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Barrel and Drum Reconditioning Industry Status Profile

Touhill, Shuckrow and Associates, Inc.
Pittsburgh, PA

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

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BARREL AND DRUM RECONDITIONING INDUSTRY STATUS PROFILE

by

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Contract No. 68-03-2905

Project Officer

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This report is an industry profile of drum reconditioning process characteristics and the current status of pollutant generation and disposal. An overview of the reconditioning industry describes number, location, and types of facilities, and estimates the volumes of drums processed. Drum characteristics, new drum production, and users are defined. In addition, personnel and operating procedures commonly employed within the industry are enumerated. Costs for new and reconditioned drums are compared.

Washing and burning processes for reconditioning are described in detail along with operating and design criteria for individual unit operations. The detailed descriptions define typical industry practice. Processing procedures which influence product quality and environmental pollutant generation are discussed. Special emphasis is given to the processing of pesticide containers, especially with regard to the ability of reconditioning procedures to detoxify pesticide residuals.

Current status of pollution control practice is defined in terms of processes and equipment, operating procedures, disposal practices, removal efficiencies, and costs. In many cases, U.S. practice is compared with that abroad.

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of the research and provides a most vital communications link between the researcher and the user community.

This report is an industry profile of drum reconditioning process characteristics and the current status of pollutant generation and disposal.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

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PREFACE

This project was undertaken prior to promulgation of regulations pursuant to the Resource Conservation and Recovery Act (RCRA). During the course of this phase of the study (November 1979 through September 1980), RCRA regulations were proposed and partially implemented. Hence, the full impact of regulations upon the drum reconditioning industry are not completely reflected in the report. Moreover, the principal sources of information and data gathered using a questionnaire sent to its members by the National Barrel and Drum Association, Inc. (NABADA) did not account for higher treatment and disposal costs expected for RCRA compliance. Data included herein is accurate and complete to March 1980. Since that time, however, there has been a rapid increase in costs especially for residue disposal. In order to make this report available in a timely fashion and to comply with contractual requirements, no attempt was made to revise data or to wait until the full impact of regulations on technology and costs become clear.

Therefore, readers should be aware that RCRA regulations will cause the industry to modify certain practices related to hazardous waste management. Similarly, the costs of pollution control for RCRA compliance certainly will rise. Nevertheless, the report does capture the state-of-the-art for the industry and permits reconditioners, governmental officials, and those that serve the industry to understand existing as well as evolving environmental requirements for the barrel and drum reconditioning industry.

ABSTRACT

This report is an industry profile of drum reconditioning process characteristics and the current status of pollutant generation and disposal. An overview of the reconditioning industry describes number, location, and types of facilities, and estimates the volumes of drums processed. Drum characteristics, new drum production, and users are defined. In addition, personnel and operating procedures commonly employed within the industry are enumerated. Costs for new and reconditioned drums are compared.

Washing and burning processes for reconditioning are described in detail along with operating and design criteria for individual unit operations. The detailed descriptions define typical industry practice. Processing procedures which influence product quality and environmental pollutant generation are discussed. Special emphasis is given to the processing of pesticide containers, especially with regard to the ability of reconditioning procedures to detoxify pesticide residuals.

Pollutant loadings are defined in terms of sources and pathways, major pollutant parameters, and generation and disposition modes. Considerable discharge data is given for air emissions, wastewater discharges, and residues. Monitoring and surveillance of reconditioning facilities is considered briefly.

Current status of pollution control practice is defined in terms of processes and equipment, operating procedures, disposal practices, removal efficiencies, and costs. In many cases, U.S. practice is compared with that abroad.

This report was submitted in partial fulfillment of Contract No. 68-03-2905 by Touhill, Shuckrow and Associates, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period November 13, 1979, to October 12, 1980. Work on this portion of the contract was completed as of October 12, 1980.

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Finally, our special thanks are extended to Mr. Stephen C. James, EPA Project Officer, for his able and interested direction of this program. His continued assistance substantially helped to insure project success.

SECTION 1

INTRODUCTION

PURPOSE

For many Americans the 208-liter (55-gallon) steel drum has become a symbol of indiscriminate disposal of toxic and hazardous wastes. To them, places like "Valley of the Drums" are frightening examples of thoughtless disposal of containers ladened with unknown contents. Unfortunately, an industry with the laudable purpose of cleaning and recycling steel drums increasingly is becoming the focus of adverse public attention. Many people assume that all drums, especially in instances where many are stored together, represent an imminent threat to public health and welfare. This intense scrutiny requires that the drum reconditioning industry meet high environmental standards.

The drum reconditioning industry performs a number of useful services. Some of these are:

- serves as a centralized collection system for used drums - some of which contain hazardous material residues
- provides treatment to the residual contents of used drums
- provides for the safe disposal of drums which can no longer be reconditioned for refilling
- obviates the need to dispose of more than 41 million steel drums annually
- recycles more than one million tons of steel annually
- conserves the energy and raw materials required to replace recycled and reconditioned drums
- places monetary value upon reconditionable drums, thus discouraging indiscriminate disposal.

The Environmental Protection Agency (EPA) recognizes the useful service performed by reconditioners, but also is alert to potential problems the industry may encounter in meeting high standards of environmental quality. As a result of this

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awareness, particularly with regard to pesticides and potentially hazardous materials, EPA contracted with the firm of Touhill, Shuckrow and Associates, Inc. (TSA) for the following purposes:

- to define representative practice for barrel and drum reconditioning by burning and washing
- to determine the environmental implications of reconditioning processes
- to recommend procedures for designing, optimizing, and retrofitting reconditioning facilities to meet rigorous environmental standards
- to determine the capabilities of the reconditioning industry to process pesticide and toxic chemical containers safely.

This report satisfies, in part, some of these purposes. This document is an industry profile of drum reconditioning process characteristics and the current status of pollutant generation and disposal. It assesses the industry state-of-the-art. Results of a field sampling and analysis program at three reconditioning plants, and recommendations for upgrading, optimizing, and retrofitting facilities to improve environmental control practices will be the subject of subsequent reports.

This report is intended for several classes of readers. First, it is expected to be especially useful to reconditioners themselves. It permits them to compare their practices with the state-of-the-art, and defines typical operating ranges for reconditioning processes.

Second, it helps governmental officials at all levels to understand the industry. It describes for these officials the problems faced by the industry in meeting environmental requirements, and defines standard practices.

Third, it helps engineers, both in-house and outside consultants, understand the reconditioning industry, and provides them with a basis for designing environmental control systems.

INFORMATION SOURCES

Publicly available literature references relating to environmental control in the steel drum reconditioning industry are sparse. Less than ten references were uncovered as a result of an extensive literature search, including six computerized data bases. On the other hand, the National Barrel and Drum Association, Inc. (NABADA) was a vital source of information in preparing this report. At its annual conventions, NABADA conducts forums on reconditioning problems and techniques. As a service to its members, NABADA transcribes the forum proceedings and issues copies to member companies. These documents provided substantial information on environmental problems faced by the industry as well as suggested solutions. Forums used extensively to prepare this report were the eleventh (1970) through the twentieth (1979).

NABADA forums illustrate that the reconditioning industry has had a good appreciation of the implications of pollution problems for many years. In many cases, solutions described at the forums have become state-of-the-art. Information used from forum discussions often is taken from many speakers over several years and assembled into tabular form. As a result, it is difficult to reference material from the forums. Hence, unless data or information is clearly attributable to a single source, references to forum discussions were not made. Suffice to say, however, forums were one of the most important sources of information in this report.

A second significant information source was transcripts of the International Conferences on Steel Drums. Four of these have been held: Tokyo (1970), London (1973), Los Angeles (1976), and Monaco (1979). These conferences have been handled in the same way as NABADA forums, and since inception have emphasized environmental concerns. Because NABADA is a major force behind the international conferences, both the content and format of the proceedings strongly resemble the forums.

A third, and probably the most important information source for this report was a questionnaire mailed by NABADA to its membership relative to the purposes of this project. NABADA and its membership actively sought to have this project undertaken. Thus, NABADA management agreed to poll its members on topics important to constructing a status profile of the industry.

The purpose of the NABADA questionnaire was to permit preparation of a drum reconditioning industry status profile which fairly and accurately reflects the current industry position. NABADA coded the questionnaires so specific facilities would not be identified; thus the status profile was intended to be indicative of average practice without reference to any specifically identified facility. Additionally, the questionnaire dealt primarily with environmental and process considerations. Items dealing with business, personnel, and proprietary matters were avoided. Appendix A shows a copy of the questions asked as part of the NABADA questionnaire.

NABADA received 49 responses to the 119 questionnaires. The coded questionnaires were provided to Touhill, Shuckrow and Associates, Inc. (TSA) for collation and analysis. Upon completion of the project, TSA returned the questionnaires for NABADA files.

Another important source of information was visits by TSA to several drum reconditioning plants. Facilities visited were:

- The Queen City Barrel Company, Cincinnati, Ohio
- Great Lakes Container Corporation, Quality Division, Quality Container Corporation, Hamtramck, Michigan
- Great Lakes Container Corporation, Pontiac Division, Pontiac, Michigan
- Bayonne Barrel & Drum Company, Newark, New Jersey
- B & F Cooperage, Inc., Philadelphia, Pennsylvania
- Universal Container Steel Drum Corporation, Trainer, Pennsylvania
- Bakerstown Container Corporation, Bakerstown, Pennsylvania
- Evans Cooperage Company, Inc., Harvey, Louisiana
- Columbus Steel Drum Company, Columbus, Ohio
- Acme Barrel Company, Chicago, Illinois
- Kaplan Container Corporation, Rochester, New York

Several of the plants were visited more than once.

In summary, five sources of information were used in preparing this report:

1) publicly available literature

2) NABADA transcripts of the forums on reconditioning problems and techniques

3) proceedings of four International Conferences on Steel Drums

4) NABADA questionnaires

5) plant visits.

PROJECT SCOPE

This assessment of barrel and drum reconditioning processes is being conducted in three parts. In the first, the current status of the industry is evaluated in terms of state-of-the-art practices for both reconditioning and pollution control. Result of this evaluation is this report - "Barrel and Drum Reconditioning Industry Status Profile". Subsequently, three reconditioning sites were selected for a sampling and analysis test program in order to define more closely pollutant sources and pathways. The final phase will be the development of recommendations for design modifications, process optimization, and retrofitting reconditioning processes.

In general, the first phase of the project, and hence this report, was organized to deal with the following topics:

- industry overview
  - number and location of facilities
  - types of facilities and volumes processed
  - drum characteristics
  - new drum production
  - drum users
  - personnel and operating procedures
  - new and reconditioned drum costs

- reconditioning processes
  - type
  - description
  - operating criteria
  - processing procedures
  - pesticide containers

- pollutant loadings
  - sources and pathways
  - parameters
  - discharge data
  - sampling and analytical procedures

- pollution control practice
  - operating procedures
  - equipment
  - disposal practices
  - removal efficiencies
  - costs

Three facilities selected for the subsequent sampling and analysis program were: 1) a large washing plant which recycles almost all of its caustic washing and rinsing solutions; 2) a large washing plant which handles substantial volumes of pesticide containers; and 3) a large burning and washing plant which is representative of typical practice. The test program serves two purposes: it confirms and supplements data presented in the status profile, and it identifies areas for emphasis in the third part of the project.

Finally, the recommendations of the third phase will define

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desirable practice and will suggest methods for attaining such practice.

SECTION 2

SUMMARY

This document is an industry profile of drum reconditioning process characteristics and the current status of pollutant generation and disposal. Five sources of information were used to prepare the report: 1) publicly available literature, 2) transcripts of National Barrel and Drum Association (NABADA) forums on reconditioning problems and techniques, 3) proceedings of four International Conferences on Steel Drums, 4) responses to a questionnaire sent by NABADA to its membership, and 5) visits to eleven drum reconditioning plants.

During 1979, about 250 reconditioners processed more than 41 million steel drums. More than 95 percent were 208-liter (55-gallon) drums, most of the rest were 114 liters (30-gallons). About two-thirds of the drums are reconditioned at washing plants which process tight head drums. The remainder, mostly open head drums, are burned in drum reclamation furnaces. Based upon the 49 NABADA questionnaire responses, facilities that only wash drums account for 39 percent of reconditioning plants. Those that only burn account for 18 percent, whereas 43 percent of the facilities perform both functions.

NABADA members represent only 48 percent of the reconditioning plants in the country, but they process more than 90 percent of all washed drums and more than 97 percent of those burned. Of the remaining reconditioning facilities, 37 percent recondition for service and resale, and 16 percent are users who process only their own drums. More than half (52 percent) of the drums washed are on a service or laundry basis; 45 percent are for resale. By comparison, only about one-third of drums burned are on a service basis; 62 percent are resold.

In 1972, the U.S. Department of Commerce determined that the reconditioning industry had sales of nearly $110 million. This would be more than $210 million in current dollars. At that time, more than 56 percent of the sales were in the Middle Atlantic and Great Lakes states. Based upon present reconditioning volumes and productivity rates, industry employment is about 7,900. The industry presently is operating at approximately 70 percent of design capacity. Nearly 51 million drums could be reconditioned annually at 100 percent of design capacity. The average plant has an 18½ day inventory, most of which is stored

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on-site.

For many years, the annual ratio of new to reconditioned drums has been nearly 1 to 1. Additionally, the ratio of new tight to new open head drums (4 to 1) has not changed over the past 10 to 12 years. However, trends show a decrease in drum thickness. For example, in 1969, 18-gage* or heavier drums comprised 64.3 percent of those manufactured that year. In March of 1980, that percentage had fallen to 41.4. This reduces the pool of potentially reconditionable drums, because thinner drums are less able to withstand the rigors of transportation and reconditioning processes.

For new drums, largest numbers are produced for the chemical (40.2 percent) and petroleum (15.2 percent) industries. Other end uses include paint and printing ink, janitorial supplies, food, and unspecified categories. A high percentage of oil and petroleum drums are reused and recycled. On the other hand, a low percentage of chemical drums are reused. Hence, it is not surprising that drums containing spent industrial chemicals or chemical residuals comprise a significant number of drums found at abandoned hazardous waste disposal sites, because such drums exit the user system quicker.

Current costs for new tight head drums of most gages are about $18. New open head drums cost around $17 for 19,20, and 20/18 gage, whereas 18 gage and heavier cost between $22 and $23. Reconditioned drums, both tight and open head, average slightly less than $12. The reconditioning laundry/service fee is nearly $6.

In a washing plant, primarily used for tight head drums, the following operations generally are employed, although there is considerable variation among plants. Drums are preflushed using a strong hot caustic solution. Subsequently, they proceed to a submerged caustic washing tank where the caustic strength is from 10 to 15 percent and the solution is heated to between 82°C (180°F) and 93°C (200°F). When drum contents are difficult to remove using caustic alone, chains are inserted into the drum along with caustic and the drum is tumbled to dislodge adhering materials. Approximately 22 percent of all washed drums are chained. If drum contents cannot be removed by chaining or are cleaned only with great difficulty, the drum heads are removed, thus converting them to open heads, and they are sent to a burning plant.

---

* The terms gage and gauge, denoting drum thickness, can be used interchangeably. Gage is the spelling preferred by the U.S. Department of Commerce, and will be used throughout this report.

After rinsing, about one-third of washing plants remove rust using hydrochloric acid washes. Tight head drums then are rinsed again, dedented, shot blasted, leak tested, and painted.

Except for a few small batch incinerators, most open head drums are burned in tunnel-type continuous furnaces. Conveyor belts move drums through the furnace at an average rate of from 6 to 8 drums per minute. During the 4 minute residence time, drum residual contents, linings, and outside paint are burned at an average furnace temperature of 677°C (1250°F). The drum temperature reaches at least 482°C (900°F). Drum temperatures higher than 538°C (1000°F) could cause warping, scaling, and structural damage. After cooling, open head drums are shot blasted, dedented, leak tested, lined, and painted.

Furnace off-gases pass through an afterburner to control air emissions. Afterburner average temperature is 810°C (1490°F) with an average residence time of 0.5 second. Air emissions also can be controlled by varying conveyor speed, spacing drums further apart, and mixing "hot" drums with normal types. The State of California requires reconditioners who burn pesticide drums to operate afterburners at 899°C (1650°F) using a 0.5 second residence time.

Natural gas is the preferred furnace fuel. Where it is uneconomical or unavailable, No. 2 oil is recommended.

Most reconditioners have established procedures for drum receiving and storage, and nearly two-thirds have oil recovery systems. At a typical plant, about 22,700 liters (6,000 gallons) of oil are recovered monthly.

About 5.4 percent of drums bound for reconditioning eventually are discarded. The bulk of these are sold for scrap.

Almost all reconditioners refuse to accept drums containing certain materials. Pesticides are refused by 83 percent of reconditioners. Other drums frequently refused are those formerly containing ink and adhesives. The industry processes over 200,000 used pesticide drums per year, although there is some uncertainty in this figure. Most are burned, but a few plants do wash significant numbers of pesticide drums. Even though the industry claims that few facilities accept pesticide drums, most plants have such drums scattered within their inventories.

Plants that process pesticide drums on a regular basis use special handling and processing procedures. Results reported by others indicate that burning (using afterburners at 899°C or 1650°F) effectively detoxifies most pesticide drums. Additionally, in washing plants, phosphorus and nitrogen-containing pesticides lend themselves to detoxification by alkaline hydrolysis. Many unanswered questions are expected to be dealt with as results of the sampling and analysis portion of this project become available.

This report placed most emphasis on liquid and solid wastes in terms of pollutant sources and pathways. Previous investigations indicated that air emissions presented little problem in drum reconditioning.

Most washing facilities either recycle and reuse caustic and rinse waters or discharge effluents into public sewerage systems. In fact, about half of all plants (including those that burn), discharge some water into public sewers. Nearly 20 percent of washing plants claim to have completely closed cycle systems. Only 10 percent are direct dischargers after treatment. Mean flow for a typical facility is 56,800 liters (15,000 gallons) per day.

Reconditioning wastewater is characterized by high pH, COD, BOD, and solids values. Also, there is wide variability in wastewaters depending upon the types of drums processed. There is some evidence of hazardous organics in small concentrations in some reconditioning wastewater.

The biggest problem facing reconditioners is the need to provide safe, economical, and environmentally acceptable means for residuals management. Evolving solid and hazardous waste management regulations are expected to have major impact on the industry. On the average, drums received by reconditioners contain 2.5 liters (0.65 gallons) or 2.5 kg (5.4 pounds) of residues. Just as caustic washing solutions have high pH, COD, BOD, oil and grease, and solids concentrations, so do caustic sludges, only in much higher amounts. More than 80 percent of solids emanating from drum reconditioning are disposed in landfills. Incineration of these solids is increasing and will continue to at an accelerated rate as the impact of RCRA regulations are felt.

Presently, surface runoff at reconditioning facilities is not being handled to any extent.

For air pollution control, all burning plants use afterburners. In addition, 37 percent of burning plants use other equipment as well, including scrubbers, packed towers, baghouses, and dust collectors. (Dust collectors also are used for shot blasters at washing plants).

Most commonly used water pollution control equipment includes: screens, oil/water separators, flocculation and sedimentation tanks, filters, and dissolved air flotation units. Moreover, many reconditioners tend to fabricate their own pollution control systems as opposed to using commercially available products. Operating procedures such as preflushing, stream segregation, and cascading water use are important adjuncts to pollution control equipment.

A typical reconditioner pays about $400 per month in sewer surcharges. Flow surcharges average $0.119/1000 liters ($0.449/1000 gallons), and BOD and total suspended solids cost $0.112/kg ($0.051/pound) of material for concentrations greater than about 200 mg/1.

Almost 90 percent of water used by reconditioners is purchased from local public or private water distribution systems at an average cost of $0.23/1000 liters ($0.86/1000 gallons). Other utility costs, principally gas and electricity, average approximately $66,000 per year for a typical plant.

Average residue disposal costs are $0.15 to $0.17 per reconditioned drum.

Recently, reconditioners have spent 20 to 50 percent of their capital budgets for pollution control. Presently, the industry has $12.7 million in installed pollution control equipment, $9.1 million of which is undepreciated (assuming 10-year life and straight line depreciation). Annual operations and maintenance costs for pollution control equipment are $5.5 million or around $45,000 for a typical plant.

Pollution control costs per reconditioned drum are in the $0.35 to $0.38 range.

SECTION 3

RECONDITIONING INDUSTRY OVERVIEW

NUMBER AND LOCATION OF FACILITIES

The U.S. Department of Transportation has registered more than 500 reconditioners of DOT specification 17 series steel drums (1). As shown in Table 1, 429 DOT registered drum reconditioners are listed as active, while 80 are inactive. The table also shows that there are 129 members of the National Barrel and Drum Association, Inc. (NABADA) who actively recondition drums. Ten of these are Canadian facilities. In addition, there are nine NABADA members who are dealers only and are not counted in the U.S. total of 119. The final column in the table indicates the location of the 49 members who responded to the NABADA questionnaire.

Other sources of information indicated that the number of reconditioners listed as active by DOT was inordinately high. For example, the Department of Commerce *1972 Census of Wholesale Trade* (2) reported only 263 reconditioners. Likewise, an industry survey in 1974 by W. & H. Industries, Inc. (3) cited only 211 reconditioning facilities. An attempt was made to reconcile the apparent disparity in numbers. A random number generation technique was used to pick for interrogation 25 DOT-approved, active reconditioners who were not NABADA members. The purpose was simply to ask whether they in fact were active reconditioners, and if so, how many drums they burned or washed per day.

Of the 25 inquiries, 11 (44%) were inactive, out of business, or incorrectly listed as reconditioners. Another 4 (16%) only air-tested, leak-tested, or refilled new drums or those cleaned by others. Of the remainder, 7 (28%) reconditioned drums as a service, and 3 (12%) reconditioned for their own use. All service reconditioners washed drums with only one (4%) burning also. These facilities washed an average of 150 drums/day, and the single burning plant had an output of 150 drums/day. The average output for those who reconditioned for their own use was 49 drums/day by washing only.

On the basis of this significant random sampling, the DOT number was revised in the following way:

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TABLE 1. DOT REGISTERED AND NABADA MEMBER RECONDITIONERS

STATE	DOT APPROVED ACTIVE	DOT APPROVED INACTIVE	NABADA MEMBERS TOTAL	NABADA MEMBERS RESPONDERS
AK	29	1	0	0
AL	6	1	2	1
AR	3	0	0	0
AZ	3	0	0	0
CA	35	2	9	2
CO	4	1	3	1
CT	3	1	1	1
FL	9	1	4	1
GA	10	2	5	2
HI	1	0	0	0
IA	6	0	1	1
IL	21	5	7	2
IN	13	1	1	0
KS	6	1	1	0
KY	7	1	2	0
LA	7	2	0	1
MA	18	2	2	1
MD	5	1	2	1
ME	1	0	0	0
MI	20	8	6	2
MN	6	2	4	1
MO	8	3	3	0
MS	1	0	0	0
NC	18	1	3	2
NE	1	0	1	0
NH	4	0	1	0
NJ	20	4	6	1
NY	26	6	8	6
NM	0	0	1	1
OH	28	5	14	4
OK	10	2	1	1
OR	4	2	1	0
PA	19	3	11	5
RI	4	1	2	0
SC	5	0	2	1
TN	12	5	1	0
TX	25	7	3	1
UT	4	3	1	1

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TABLE 1. (cont.)

STATE	DOT APPROVED ACTIVE	DOT APPROVED INACTIVE	NABADA MEMBERS TOTAL	NABADA MEMBERS RESPONDERS
VA	7	0	3	1
WA	4	2	2	1
WI	11	1	4	1
WV	0	2	0	0
WY	1	0	1	1
Unspecified	-	-	-	4
CANADA	4	1	10	1
	429	80	129	49

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DOT Active List	429
minus: NABADA Members on DOT Active List	103
Random Sample Field	326
minus: Inactive, out of business, or incorrect listing	143
minus: Air-test, leak-test, or refill	52
Non-NABADA Reconditioners	131

Service - 92
Own Use - 39

Hence, it was estimated that there are about 250 reconditioners in the U.S.; 119 (48%) are NABADA members who recondition as a service, 92 (37%) are non-NABADA service reconditioners, and 39 (16%) are user-reconditioners.

Table 2 gives an indication of the distribution of the U.S. reconditioning industry regionally, in 1972 both in terms of numbers and sales volume.

TYPES OF FACILITIES AND VOLUMES PROCESSED

Of the 49 responders to the NABADA questionnaire, 19 (39%) were washing facilities, 9 (18%) were burning facilities, and 21 (43%) both burned and washed. These results roughly correspond to those of an earlier study performed for NABADA (4). This previous report showed that in 1973, approximately 45% of facilities were for drum washing only, 14% for burning, and 41% of the reconditioning plants both burned and washed. Reduction in the relative percentage of washing plants illustrates the demise of smaller plants. The trend appears to favor consolidation and a better competitive position for the larger reconditioners.

Annual drum reconditioning volumes for 1979 are listed in Table 3. Volumes were generated in the following way: washing and burning volumes for NABADA responders to the questionnaire were divided by 0.412 (indicative of 49 responses from 119 members) to arrive at a NABADA total. Non-NABADA service reconditioners average an output of 150 drums/day for both washing and burning. As mentioned earlier, there are 92 such service reconditioners, 13 of whom also burn. Total working days were assumed to be 260. For those who recondition for their own use, daily washing volume of 49 drums/day was used for the 39 facilities in this category.

The estimated volume of drums reconditioned during 1979 from all sources was about 41 million. NABADA members were

TABLE 2. RECONDITIONER SALES BY REGION (2) (1972 DOLLARS)

REGION	NUMBER OF RECONDITIONERS	SALES (in thousands)
New England	15	5,085
Boston SMSA	6	1,384
Middle Atlantic	86	32,863
New York SMSA	18	6,969
Newark SMSA	13	9,023
Philadelphia SMSA	16	7,248
East North Central	66	28,535
Cleveland SMSA	12	3,035
Detroit SMSA	5	1,708
Chicago SMSA	18	8,521
West North Central	11	2,821
South Atlantic	22	14,940
East South Central	3	280
West South Central	21	7,453
Houston SMSA	4	1,401
Dallas-Ft. Worth SMSA	6	2,019
Mountain	7	1,503
Pacific	32	16,457
Los Angeles SMSA	11	4,729
San Francisco SMSA	6	3,895
TOTAL	263	109,937

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TABLE 3. ANNUAL DRUM RECONDITIONING VOLUMES

SOURCE	PLANT DESIGN CAPACITY		ESTIMATED ESTIMATED VOLUME (1979)		
	WASH	BURN	WASH	BURN	TOTAL
CAPS NABADA r Responders	12,567,100	8,559,200	9,220,640	5,854,940	15,075,580
NABADA CAPS Total	30,520,100	20,786,600	22,393,000	14,219,000	36,612,000
Non-NABADA CAPS Service	--	--	3,588,000	507,000	4,095,000
Non-NABADA CAPS Own Use	--	--	497,000	--	497,000
		TOTAL	26,478,000	14,726,000	41,204,000

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responsible for nearly 90 percent of this volume. In the case of burning volume, NABADA members processed almost 97 percent of the drums burned during 1979. The percentages of drums washed and burned by all reconditioners are 64 and 36, respectively.

Table 3 further illustrates that NABADA reconditioners are operating only at about 70 percent of design capacity. Specifically, washing volume is at 73 percent of design capacity, while burning volume is at 68 percent. At design capacity, NABADA members can recondition more than 51 million drums per year. True operating capacity is less than this amount, but by how much is unknown. Two problems now are affecting the utilization of industry capacity adversely. The first is an economic recession, the impact of which will mirror that upon manufacturing industries in general. A longer term, and more serious problem for the reconditioning industry is the shortage of heavier gage, reconditionable steel drums. Implications of this condition on the industry and the environment will be discussed in another report.

Generally, washing facilities are larger than those that burn. Also, plants that perform both operations are much larger than those that only do one. Table 4 shows that such is the case in terms of design capacity and actual production.

TABLE 4. MEAN DAILY DRUM PRODUCTION
(in drums/day)

	WASHING	BURNING	WASH and BURN	
			WASH	BURN
Design Capacity	862	838	1,522	1,209
Actual Production	690	566	1,064	830

DRUM CHARACTERISTICS

Drums are reconditioned either as a service (laundry) or for resale. Moreover, during reconditioning some drums prove to be unsuitable for reuse and are discarded. Table 5 shows the relative distribution of drums processed at washing and burning facilities.

TABLE 5. DISPOSITION OF RECONDITIONED DRUMS

	WASH	BURN
Resale	44.7%	61.9%
Service or Laundry	51.7%	32.9%
Discards	3.5%	5.2%

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The percentage of drums discarded as noted in Table 5 indicates that drums may be reconditioned roughly 20 to 30 times. However, it is recognized within the industry that a typical 18-gage drum can be reconditioned about eight times (6). This means that some drums are rejected before receipt for reconditioning. The fate of the rejected or "graded-out" drums was not determined in this study. There are more tight head drums (washed) used for service or laundry than open heads (burned) because oil companies are significant users and recyclers of heavy gage tight head drums. The higher percentage of discards in the burning process results because the normal progression of reconditioned drums is toward open heads. For example, difficult to clean tight head drums are deheaded and converted to open heads. Unless a burning plant is operated properly, discards can increase because of drum warping and flaking at high temperatures.

The vast majority of reconditioned drums are 208 liter (55-gallon) containers: 97.5 and 95.2 percent for washing and burning operations, respectively. Almost all of the remainder are 114 liter (30-gallon) drums with 2.1 percent in washing facilities and 4.6 percent in burning plants. Other sizes represent insignificant percentages.

The average reconditioning plant has sufficient inventory on hand to represent an 18½ day backlog. This figure was determined in the following way: the 49 responders to the NABADA questionnaire indicated a total inventory of about 1,065,000 drums before processing. The average daily number of drums processed by these plants is about 58,000. Total inventory divided by daily production is about 18½.

The typical facility stores about 18,500 drums on-site, and about 3,200 off-site. The average number for off-site storage was skewed because of one plant which stored 100,000 drums off-site out of a total of 156,000. If this plant was neglected from the calculations, then the average is about 1,200. In fact, only 10 out of 49 responders reported any off-site storage at all.

The inventory considerations described above pertain only to reconditioning facilities. Drum brokers, who collect from users and subsequently sell to reconditioners, were not considered in the inventory evaluation. Numbers of drums in the brokers inventories could be significant.

NEW DRUM PRODUCTION

The reconditioning industry is strongly influenced by the number, gage, and size of steel drums in circulation. An industry rule-of-thumb is that the annual ratio of new drums produced to reconditioned drums is roughly 1 to 1. This held true for 1979 wherein the Department of Commerce estimated new drum production for all sizes at about 40 million (5), and reconditioned volume was almost 41 million. Even though this ratio has not varied over the years, the kinds of drums produced have. Table 6 shows that even though the ratio of tight to open head drums has remained constant over the past ten years, drum thickness has not. In 1969, 64.3 percent of new steel drums were 18 gage and heavier. The percentage in March 1980 was 41.4 according to the M34K report of the Bureau of the Census for that month.

Reduction in drum thickness correspondingly reduces the ability of the drum to withstand the rigors of transportation and the reconditioning process. Hence, as thinner drums enter the user system, overall inventory is lessened because thinner drums exit sooner. The number of times various gage drums can be recycled and reconditioned has been estimated to be: 16 gage - up to 15 times; 18 gage - 8 times; 20/18 gage* - 3 times; and 22 gage - new drum for each fill (6).

U.S. production of new and reconditioned drums exceeds that of most of the major free world industrial countries combined. Examination of the figures shown in Table 7 show several interesting trends. Reconditioning in West Germany shows substantial growth over the past seven years. On the other hand, reconditioning in Japan has declined sharply over the last eleven years. This has been attributed to the vastly increased use of tank trucks to transport oil and petroleum products. There has been a marked decline in numbers of reconditioning companies and facilities in Japan since 1969, when there were 180 companies and 248 facilities. This declined to 150 companies and 200 facilities in 1971. Figures for 1979, report 120 companies and 140 reconditioning facilities. By comparison, there are 30 companies in the United Kingdom, and 10 plants in the Union of South Africa (8 washing plants and 2 burning.)

DRUM USERS

New drum users and reconditioner customers were investigated in order to determine the fate of steel drums. Bureau of Census, Current Industrial Reports on steel shipping barrels, drums, and pails (also known as the M34K reports) provide detail on numbers of drums produced and end users. Table 8 enumerates new drum end use for the period 1969 to 1979. No data on end use is available for 1974 and 1975. Additionally, the report format changed in 1976, with greater percentages of drums produced being coded in the unspecified category. Exact definitions for each of the end use categories are given in Appendix B.

Ten years ago, nearly three-quarters of all new drums were manufactured to contain chemical and petroleum products. More

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* 18 gage head and bottom, and 20 gage body

TABLE 6. TYPES OF NEW STEEL DRUMS PRODUCED

	PERCENT OF TOTAL (%)	
DRUM TYPE*	1969	MARCH 1980
TIGHT HEAD		
- 18 gage and heavier	50.9	33.4
- 19 and 20 gage (including 20/18)	31.2	47.0
OPEN HEAD		
- 18 gage and heavier	13.4	8.0
- 19 and 20 gage (including 20/18)	4.5	11.6

* 50 gallon and larger

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TABLE 7. FOREIGN RECONDITIONED AND NEW DRUM PRODUCTION VOLUMES

COUNTRY	YEAR	NEW DRUM PRODUCTION (in millions)	RECONDITIONED DRUMS (in millions)
Belgium	1978	1.3	1.5
France	1972	-	2.3
	1978	4.8	2.5
Japan	1969	3.3	30.0
	1973	10.2	-
	1974	-	23.0
	1975	7.3	-
	1978	8.8	18.0
Netherlands	1978	3.3	0.8
South Africa	1978	-	1.2
Sweden	1978	-	0.3
United Kingdom	1972	5.5	6.0
	1978	-	6.0
West Germany	1973	4.5	3.0
	1976	7.0	5.2
	1978	7.0	7.0

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TABLE 8. NEW DRUM END USE

		END USE							
YEAR	NO.* %	CHEMICAL	PETROLEUM	PAINT & PRINT. INK	JANITOR SUPPLIES	FOOD	OTHER	UNSPECIFIED	TOTAL
1969	No.	10,287	5,326	2,030	637	1,310	1,081	-	20,671
	%	49.8	25.8	9.8	3.1	6.3	5.2	-	100
1970	No.	9,765	5,069	1,839	628	1,314	1,122	-	19,737
	%	49.5	25.7	9.3	3.2	6.7	5.7	-	100
1971	No.	9,513	4,730	1,860	681	1,366	1,025	-	19,175
	%	49.6	24.7	9.7	3.6	7.1	5.3	-	100
1972	No.	11,516	5,075	2,313	828	1,888	1,742	-	23,362
	%	49.3	21.7	9.9	3.5	8.1	7.5	-	100
1973	No.	13,091	5,621	2,571	948	1,751	3,727	-	27,709
	%	47.2	20.3	9.3	3.4	6.3	13.5	-	100
1974	No.				NO	DATA			
	%								
1975	No.				NO	DATA			
	%								
1976	No.	16,320	5,432	2,064	1,267	1,602	3,346	7,421	37,452
	%	43.6	14.5	5.5	3.4	4.3	8.9	19.8	100
1977	No.	16,196	6,428	2,608	1,349	1,879	4,052	8,749	41,261
	%	39.3	15.6	6.3	3.3	4.6	9.8	21.2	100
1978	No.	16,196	6,729	3,085	1,528	1,764	4,023	9,377	42,702
	%	37.9	15.8	7.2	3.6	4.1	9.4	22.0	100
1979	No.	18,124	6,849	2,972	1,402	2,306	4,407	9,068	45,128
	%	40.2	15.2	6.6	3.1	5.1	9.8	20.1	100

* (in thousands)

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recently this percentage has slipped to between 55 to 60 percent, although absolute numbers of drums destined to contain these products continues to rise.

Prior to 1972, end use data was detailed in the M34K reports. Use figures were broken down by gage and whether the drum had a tight or open head. Table 9 reports the percentage distribution of drum end use according to gage and head for the four-year period 1969 to 1972. Subsequently, information was broken down into fewer use categories. As indicated earlier, there has been a strong shift toward lighter gage drums (20 gage and lighter) (See Table 6). Data in Table 9 shows that more than 60 percent of new 20 gage drums were used for industrial chemicals during the 1969 to 1972 period. There is reason to believe that current use is nearly the same.

New and reconditioned drum usage is compared in Table 10. New drum end use figures are from the 1979 summary M34K report. Data on the shippers of drums to reconditioners were obtained from the Checchi Report (4), and from responses to the NABADA questionnaire. Several conclusions may be drawn from the data:

- There is fairly good agreement between the Checchi Report and NABADA responses.
- There is a high percentage of reuse and recycling of drums by oil and petroleum users.
- Reuse and recycle of drums containing industrial chemicals is low.
- There appears to be a moderate amount of reuse and recycling of paint and printing ink drums.
- It is not surprising that drums containing spent industrial chemicals or chemical residuals comprise a significant number of drums found at abandoned hazardous waste sites, because such drums exit the user system quicker.

Reconditioning in foreign countries is influenced strongly by the uses to which the drums have been put. In Table 11, users of reconditioned drums are listed. Data represent estimates (very rough in some cases) which are indicative of the kinds of drums processed. The proportion of chemical drums processed in Japan is rising rapidly. This is due to the strong trend toward use of tank trucks for transport of petroleum-based products.

Reconditioning processes in West Germany are strongly influenced by the large proportion of oil drums processed. Oil drums tend to be easier to wash than other kinds.

TABLE 9. DRUM END USE PERCENTAGE DISTRIBUTION BY GAGE (1969-1972)

	18 GAGE (%)		20 GAGE (%)		
USE	Tight Head	Open Head	Tight Head	Open Head	TOTAL
Chemicals	20.4	5.7	20.4	3.1	49.6
Petroleum	16.5	2.0	5.4	0.5	24.4
Paint and Printing Ink	3.8	3.1	2.1	0.7	9.7
Janitorial Supplies	0.5	0.1	2.5	0.2	3.3
Food	4.1	1.7	0.8	0.5	7.1
Other	2.1	1.9	1.6	0.5	6.1
TOTAL	47.4	14.5	32.8	5.5	100.2

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TABLE 10. NEW AND RECONDITIONED DRUM USAGE

USE	NEW DRUM END USE (1979) (%)	SHIPPERS TO RECONDITIONERS (%)	
		Checchi(4)	NABADA
Food	5.1	-	6.8
Oil & Petroleum	15.2	37.8	36.2
Paint	{6.6	19.0	10.0
Ink		-	4.8
Adhesive	-	9.6	6.8
Resins	-	-	8.8
Industrial Chemicals	40.2	14.1	15.6
Pesticides	-	2.9	0.5
Cleaning Solvents	-	11.3	8.8
Janitorial Supplies	3.1	-	-
Other	9.8	5.3	1.8
Unspecified	20.1	-	-

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TABLE 11. FOREIGN USERS OF RECONDITIONED DRUMS

COUNTRY	YEAR	USERS (as % of Total)							
		Chemicals	Oil & Petroleum	Paints	Emulsions	Petro-Chemicals	Food	Adhesives & Resins	Other
Japan	1969	16.0	68.6	5.6	1.7	-	-	-	8.1
	1973	37.1	44.3	-	-	12.1	-	-	6.5
	1974	33.5	46.1	-	-	13.1	-	-	7.3
	1975	39.5	38.5	-	-	13.8	-	-	8.3
	1976	30	50	10	-	-	5	-	5
	1979	60	23	-	-	-	-	-	17
West Germany	1976	15	80	-	-	-	-	-	5
France	1976	-	40	-	-	-	-	50	10
United Kingdom	1976*	(5)	(1)	(2)	(4)	(1)	-	(3)	-

* Number in parenthesis denotes most frequently processed drums from highest (1) to lowest (5).

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PERSONNEL AND OPERATING PROCEDURES

The drum reconditioning business is highly competitive; hence, individual companies are guarded about information released. One such subject is number of employees. In fact, this topic is so sensitive that the NABADA questionnaire never broached the subject. There is, however, a rule-of-thumb which has been used to determine average productivity levels. This figure for production employees is assumed to be 20 drums/day/man. Because annual drum production was determined to be 41 million, this translates to total industry employment of about 7,900.

Japanese productivity ranged between 26.0 and 27.5 drums/day/man in the early 1970's. A short-range productivity target of the Japanese is 42.1 drums/day/man; while, a long-range target is 75.

Only one responder to the NABADA questionnaire operated more than one shift. In that particular instance, the reconditioning company was working from a large off-site inventory. Occasionally, reconditioners will extend hours during peak seasons, e.g. 10 hour days; but, rarely will such overtime be extended for long periods.

COSTS

The report entitled, "Steel Shipping Drums and Pails", (also known as the M34K report) issued by Bureau of the Census gives new drum prices monthly. Table 12 lists new drum prices for the years 1977 and 1978, as well as prices for March of 1979 and 1980. Figures were taken directly from the M34K reports.

Prices of new and reconditioned drums also were part of the NABADA survey. These data are reported in Table 13. Note that the NABADA survey prices do not reflect drum gage or condition. Figures, however, compare well with those in Table 12.

New and reconditioned drum prices are rising rapidly, reflective of overall economic conditions. From 1950 to 1966, reconditioning prices rose only 15 percent, whereas from 1967 to 1973, the increases for new and reconditioned drums were from 30 to 100 percent dependent upon the type of drum. More recent price increases have been at least in that range.

A rule-of-thumb used by foreign reconditioners is that the typical international price of a reconditioned drum is between 75 to 80 percent of a new one. U.S. prices, according to the NABADA survey are 67.2 and 61.2 percent of new for reconditioned tight and open heads, respectively. International comparative prices for drums are shown in Table 14.

TABLE 12

PRICES OF NEW DRUMS
(Bureau of the Census Survey)

	PRICE (in dollars)*			
	March 1980	March 1979	Year 1978	Year 1977
Tight Head				
18 gage and heavier	18.07	17.26	16.51	15.50
19 and 20 gage**	18.39	16.86	16.33	14.43
Open Head				
18 gage and heavier	22.37	19.33	18.42	17.77
19 and 20 gage**	16.82	15.60	14.71	13.97

* Drum price is at the point of production. It includes the net sales price, f.o.b. plant, after discounts and allowances, exclusive of freight charges and excise taxes.

** Includes 20/18 gage drums.

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TABLE 13

PRICES OF NEW AND RECONDITIONED DRUMS
(NABADA Survey)

Drum Type	Mean Price ($)	Standard Deviation	Range Min.	Range Max.
New Tight Head	17.47	2.66	13.50	27.00
New Open Head	19.42	4.31	15.00	34.00
Reconditioned Tight Head	11.74	1.33	9.00	15.19
Reconditioned Open Head	11.89	1.79	9.75	15.50
Laundry/Service Fee	5.78	1.18	4.00	9.80

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TABLE 14

PRICES OF NEW AND RECONDITIONED DRUMS
(as reported at International Conferences)

Country	Year	Drum Gage	Price ($) New	Price ($) Recon.	Price ($) Laundry	Price ($) Ship.
U.S.	1941-45	-	-	1.40-1.65	-	-
U.S.	1970	18	7.00	2.50	-	-
U.S.	1970	18	6.50	2.00	-	0.50
U.S.	1970	20/18	6.50	-	-	-
Canada	1973	-	9.00	2.25	-	1.20
Canada	1976	-	8.00^{+}	3.25^{t}	-	2.00^{e}
Canada	1976	-	-	4.00^{o}	-	4.00^{w}
Japan	1976	16	11.70	9.30	2.70-3.30	-
Japan	1976	18	10.00	8.00	-	-
Nigeria	1976	22	18.00^{t}	13.00	8.00	-
U.K.	1976	18	22.23	-	-	-
U.K.	1976	19	21.18	-	-	-
U.K.	1976	20	19.91	-	-	-
U.K.	1976	first grade	-	4.78	-	-
U.K.	1976	good quality plain	-	11.95	4.18	-
U.K.	1976	-	-	$14.34\text{-}15.54^{o}$	-	-
South Africa	1976	20/21	15.00	7.00	3.60	-

Notes: t - tight head
o - open head
e - East
w - West

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PLASTIC CONTAINERS

An attempt continues by some to sell plastic containers as substitutes for 114 (30) and 208-liter (55-gallon) steel drums. Most such plastic self-supporting containers are made of polyethylene. Reconditioners have found that steam is the only effective cleaning method for polyethylene. Moreover, cleaning is difficult because of the nature of the plastic surfaces and cavities in the heads.

After a brisk start in production in the mid to late-1960's, growth began to sag in the early-1970's. For example, in 1972, European production growth dropped to 3 percent after a year of 15 percent growth. Since then plastic container growth has been modest, not threatening the predominant use of steel containers. Some reconditioners speculate that the reason for this advance is that the chemical industry, major user for this type of container, is urging the use of such containers needed mainly by their industry.

Despite increased use of plastic containers, reconditioners throughout the U.S. and Europe have concluded that it is unlikely that such containers will be serious competitors to steel drums in the near future. Major reasons are the difficulty in reconditioning and disposing of spent plastic containers.

At the Second International Conference on Steel Drums held in London (1973), Mr. Franz Sauer of West Germany identified the following advantages and disadvantages of plastic containers. He, too, concluded that the difficulty of reconditioning proves to be a major obstacle to widespread use.

"Advantages of the plastic drum:

1. The chance for use of own raw materials produced by the chemicals department of the mineral oil companies for the production of these drums.
2. No rust, nor corrosion - neither internally nor externally.
3. Seamless production.
4. Low dead weight.
5. Resistance against corrosive filling materials."

"Disadvantages of the plastic drum:

1. Its life is limited, as the producers of the raw material extend their quaranty only up to 18 months. There is further the possibility of fatigue of the

material which may result in the formation of cracks. For these reasons the plastic drum hardly is qualified to be used as a returnable drum.

2. For use as a one-way drum, it is too expensive. Furthermore it is not possible to destroy the drum after completion of one trip.

3. Handling out of the storage yard and during transportation is rendered substantially more difficult by its bulgy shape, which nevertheless has to be maintained for reasons of stability.

4. Lacking capability to be stacked, even if palleted. Practice has proved that no more than 3 drums may be piled one upon the other, as otherwise palleted stacks will break away, especially on reaction of insulation.

5. Very sensitive against implosion. The latter originates by formation of vacuum when filled with hot contents or after cleaning, in cases where the drum is closed while still warm.

6. It is only possible to produce the drum as a monochromatic one. Unless it is additionally painted, the drum cannot be supplied as a multicoloured one. This would mean that many fillers would have to change their domestic colour.

7. Cleaning is rendered difficult by its raw surface and the cavities on its top and bottom heads.

8. Due to the pores, external cleaning also is rather difficult. To put the drum into a nearly new condition - as is done in the case of a steel drum - it is absolutely necessary to paint the drum additionally."

Elsewhere in this report the costs of new and reconditioned steel drums, as well as the costs of cleaning and pollution control are discussed in detail. The following figures for plastic containers are shown for comparison (Table 15). Those who steam clean plastic drums claim a useful life of 25 to 30 trips, with a cleaning cost of $0.25/trip (1971 dollars).

TABLE 15. PRICES FOR PLASTIC DRUMS
(1971 Dollars)

SIZE (gal)	PRICE Each	 Lots over 1000
15	$ 7.50	$ 4.25
30	13.50	8.10
55	21.60	12.95

SECTION 4

RECONDITIONING PROCESSES

PROCESS TYPES

Steel drums are processed by either washing or burning. Each method has several variations. Because tight head drums almost always are washed, reconditioners frequently refer to washing facilities as tight head plants. Conversely, open head drums are processed almost exclusively by burning; hence, burning operations often are called open head plants. Figure 1 shows a typical tight head drum. An open head drum is almost the same except that the top is replaced by a lid. The flanged lid and top chime are joined by a compression-type steel ring fitting. Neoprene or similar material gaskets are used to effect a good seal. Sometimes the open head drum lid does not have bung holes.

Washing most often is done using caustic solution. Infrequently, only steam washing is used for tight head drums. Steam cleaning is for so-called "easy-to-clean" drums where there is little residual which is readily rinsed with water. Most often steam-cleaned drums are in dedicated use and are laundered rather than resold. One such plant cleans 1,500 oil drums/day using steam followed by a hot dilute acid wash using rotary nozzle sprays.

Most commonly, washing is done with a strong, hot caustic solution. When drum contents are difficult to remove using caustic alone, chains are inserted into the drum along with the caustic and the drum is tumbled to dislodge adhering materials. More detailed descriptions of the caustic washing operation follow later in this section.

Solvent washing has been used by several reconditioners in Europe. Specifically, some West Germans and Swiss use trichloroethylene (TCE) to wash drums. At one West German plant, TCE is used only to clean difficult drums. The principal advantage claimed for solvent washing by TCE is its ease of regeneration when compared with caustic solutions. Typically, TCE is used in conjunction with low pressure steam (about 35 kPa or 5 psi). In one plant, TCE is injected at 490 kPa (70 psi) at a rate of 53 liters (14 gallons) per minute. Residence time is variable, but maximum is about 5 minutes. Spent trichloroethylene is cleaned

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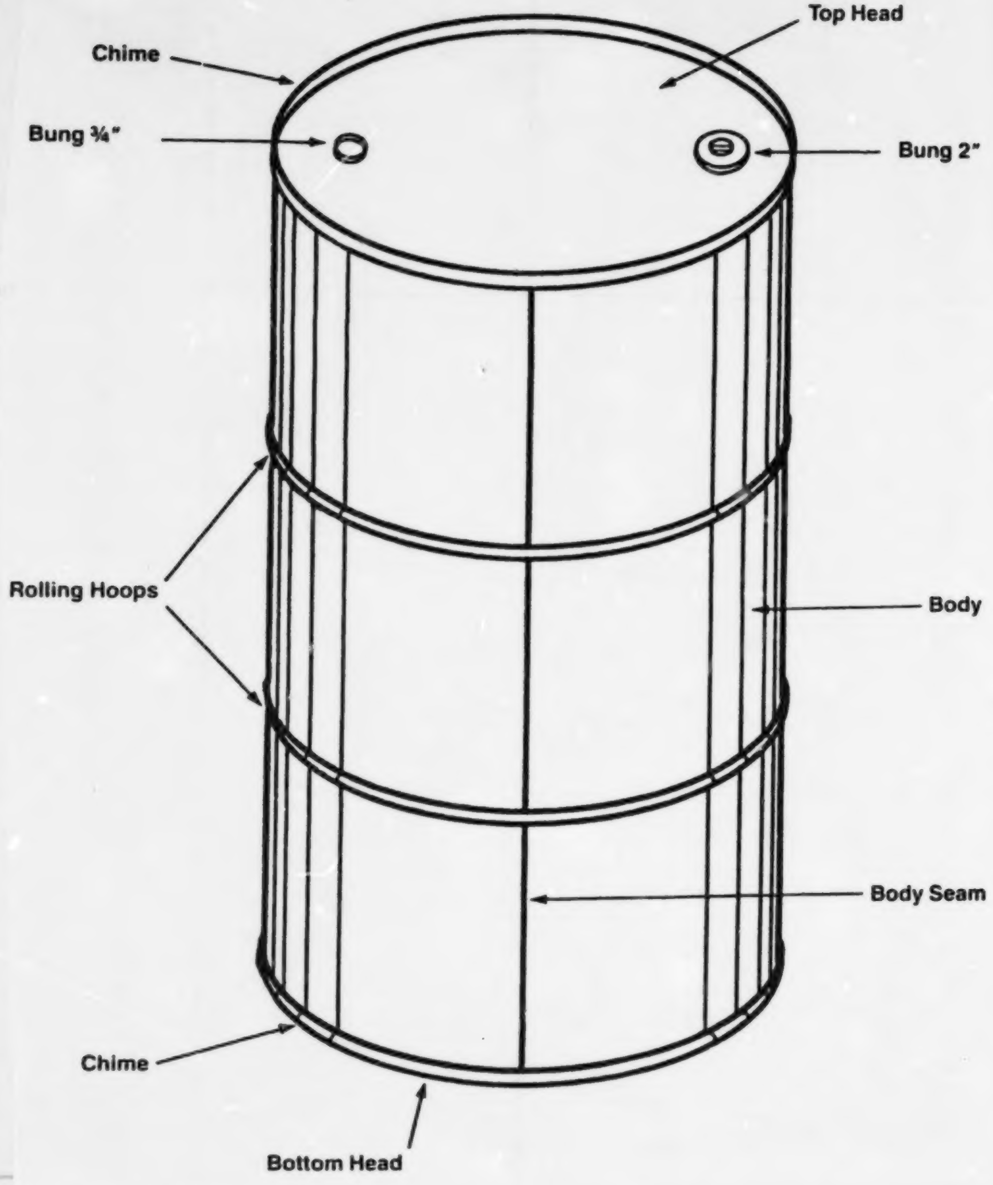
FIGURE 1

Typical Tight Head Drum


Top Head
Chime
Bung ¾"
Bung 2"
Rolling Hoops
Body
Body Seam
Chime
Bottom Head

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by distillation.

Use of TCE has positive and negative aspects. Positively, TCE is an excellent degreaser and cleaning agent. It is a solvent for fats, waxes, resins, oils, rubber, paints, varnishes, cellulose esters and ethers. It is practically insoluble in water and has a boiling point of 87.2°C; thus, it is highly amenable to distillation processing. Negatively, moderate exposure can cause symptoms similar to alcohol inebriation. Higher concentrations can have a narcotic effect. TCE is a confirmed animal carcinogen. No reconditioners in the U.S. were identified as being regular TCE solvent washers. In Japan, a few reconditioners have used orthosilicic acid for better fats removal.

Two types of furnaces are used to burn steel drums: batch and continuous tunnel. Batch furnaces are used at smaller installations. These furnaces are designed to burn one 208 liter (55-gallon) drum at a time. They also accomodate 114 liter (30-gallon) drums. The drum is enveloped by several burners fueled by oil or natural gas, and drum residual contents, lining, and outside paint are burned during a nominal 4-minute period. Because operating costs of drum reclamation furnaces are high, reconditioners use them to prepare drums for subsequent cleaning by shot blasting. Thus, complete combustion of all organic residues is not the primary intent. Rather, the purpose is to burn as much as possible leaving the removal of resultant char to subsequent steps. Drum temperatures reach at least 482°C (900°F). Continuous tunnel furnaces are much more complex. They process up to 4 to 5 drums/min for larger burning plants. Both types of processing will be described in greater detail later in this section.

PROCESS DESCRIPTIONS

Washing Process

Despite common usage of caustic washing, no two tight head reconditioning plants are the same. Certainly there are many similarities, but for maintenance or enhancement of environmental quality standards each plant must be evaluated separately. Nevertheless, a flow diagram which generally represents the caustic washing process and its many variations is shown in Figure 2.

Almost all reconditioners at washing plants perform some kind of screening upon drum pickup or delivery at the reconditioning facility. Most (more than 90 percent) will return to the shipper damaged drums, those not empty, or those containing unacceptable materials. Many reconditioners have lists of types of drums which they will not accept for processing. Moreover, NABADA and EPA recently have issued guidelines defining drum "emptiness". Both topics will be discussed as part of operating criteria and processing procedures later in this section.

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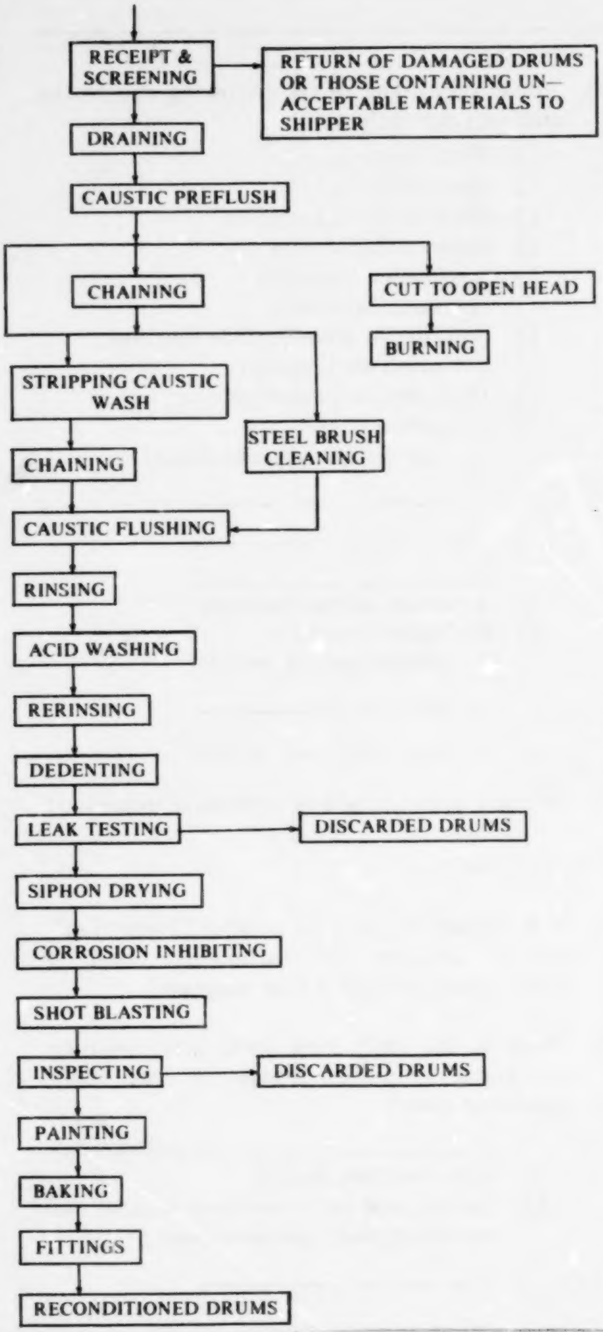
FIGURE 2

WASHING FLOW DIAGRAM


RECEIPT & SCREENING
RETURN OF DAMAGED DRUMS OR THOSE CONTAINING UN-ACCEPTABLE MATERIALS TO SHIPPER
DRAINING
CAUSTIC PREFLUSH
CHAINING
CUT TO OPEN HEAD
BURNING
STRIPPING CAUSTIC WASH
STEEL BRUSH CLEANING
CHAINING
CAUSTIC FLUSHING
RINSING
ACID WASHING
RERINSING
DEDENTING
LEAK TESTING
DISCARDED DRUMS
SIPHON DRYING
CORROSION INHIBITING
SHOT BLASTING
INSPECTING
DISCARDED DRUMS
PAINTING
BAKING
FITTINGS
RECONDITIONED DRUMS

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Drums often are drained before entering the process line, especially oil drums. Some plants have oil siphons especially for the purpose of oil recovery. After draining, drums receive a caustic preflush to remove the bulk of readily loosened material. One innovative reconditioner has proposed using steam generated by the burning of drainage and sludge to "preempty" drums before they even receive a caustic preflush. To date, nobody has used such a method.

A larger reconditioner successfully employs two preflushes. The first is a typical three minute preflush using strong hot caustic. In the second preflush an Oakite^{R} metal cleaner is used. Figure 3 is a photograph of a typical preflushing station.

Subsequent to caustic preflushing, trained plant employees judged whether drums should proceed directly to a submerged caustic washer, should be chained to remove difficult adhering material, or should be converted by deheading to open head drums, which in turn subsequently are burned. In some cases, trained employees can spot drums requiring conversion to open head even before the preflushing step.

For solvents or light petroleum products, one reconditioner estimates the caustic preflush solution can be used for 50,000 to 100,000 drums before caustic makeup and cleaning are needed. By comparison for preflushing of drums containing coatings, paints, synthetics, resins, only 10,000 to 12,000 drums can be flushed before caustic preflush rejuvenation. (Only the relative numbers are pertinent because the size of the solution reservoir was unspecified).

In some smaller plants, drums go directly from trucks to a submerged caustic washer without draining, preflushing, and sometimes even chaining steps. Clearly, this adds a significant solids burden to the caustic solution and requires more frequent caustic makeup.

Most washing plants dedent drums after all caustic washes and rinsing, usually just before chime sealing and leak testing. However, some prefer to dedent immediately after draining or caustic preflushing. Presumably, dedenting is done at this stage so that drums can be classified earlier. Also some reconditioners maintain it is easier to find dents as drums are rolled off the trucks.

Chaining typically takes place as a separate step before the submerged stripping caustic wash, or in conjunction with the submerged wash. Most often drums failing to be cleaned during chaining are sent for conversion to open heads, but some washers will try a second chaining cycle. A few reconditioners will send chained drums to a subsequent caustic flush.

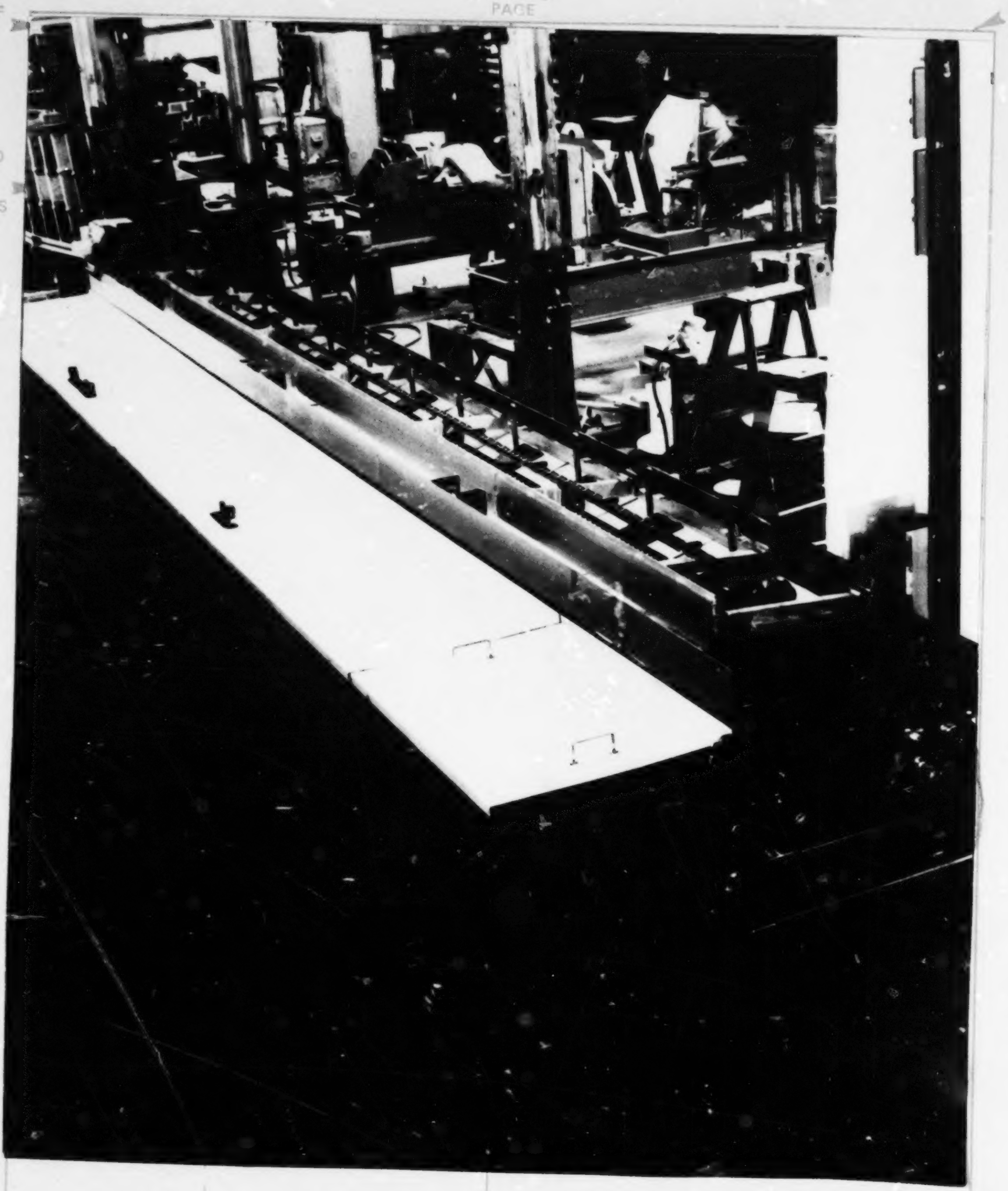

Figure 3. Typical Preflushing Station

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Chains are about 0.76 meters (30 inches) long. Typically, 6 to 20 pieces are used. A commonly used amount is 10 pieces for 20 gage drums and 10 to 12 pieces for 18 gage (about 22.7 kg or 50 pounds). Chains usually are 0.95 cm (3/8-inch), case-hardened, twist-length. Two kinds of chaining machines are employed. One of the more effective is one which rotates the drum around its vertical axis when laid on its side, and also gimbals permitting the chain to contact both top and bottom heads as the chaining machine gimbals from side to side. A second type of machine does the same thing, but does not gimbal; hence, the drums must be moved to another machine which stands the drum upright and again rotates about the vertical axis. In order to clean the other head, the drum would have to be turned over. In some cases, the heads simply are not chained.

Upon completion, chains are fished out of the drums using wire hooks. Paint drums commonly are regarded as the largest volume of drums chained. Automobile sealing compounds (some of which contain asbestos) are thought to be among the most difficult to wash, so chaining is always used with such drums. Figure 4 is a photograph of a chaining machine.

In most washing plants, drums are treated inside and out by submerging in a hot caustic bath. Drums are set on their sides with bungs removed and they rotate proceeding through the caustic bath (see Figure 5). In larger plants, drums proceed in assembly-plant style. Typically, two receiving arms automatically lower the drums into the submerger. The drums are pushed forward rotating about 20 rpm. They are held down by wheels that permit flow of the solution into the drum. One plant pumps solution over the top of the drum as it rotates to get better stripping. In this same plant, both preflush and submerger caustic tanks are insulated in order to conserve heat.

In smaller plants drums are handled batchwise, but the cleaning principle remains the same. Some plants only use hot caustic to wash the drum inside. Rotating steel brushes remove paint from the outside. This procedure is not very common.

After caustic washing, regardless of the manner in which it was done, drums are rinsed. Increasingly, reconditioners recycle their rinsewater solutions. Finished drum quality improves with better rinsing, therefore there is a concerted attempt to keep rinsewater clean.

About 40 percent of washers follow the caustic rinse step with an acid wash. The reason for an acid wash primarily is to remove rust spots. Rerinsing follows the acid wash. A corrosion inhibition step is used in about half of the washing plants. Its location in the flow train varies.

Some washers prefer to siphon dry after rinsing, then dedent,

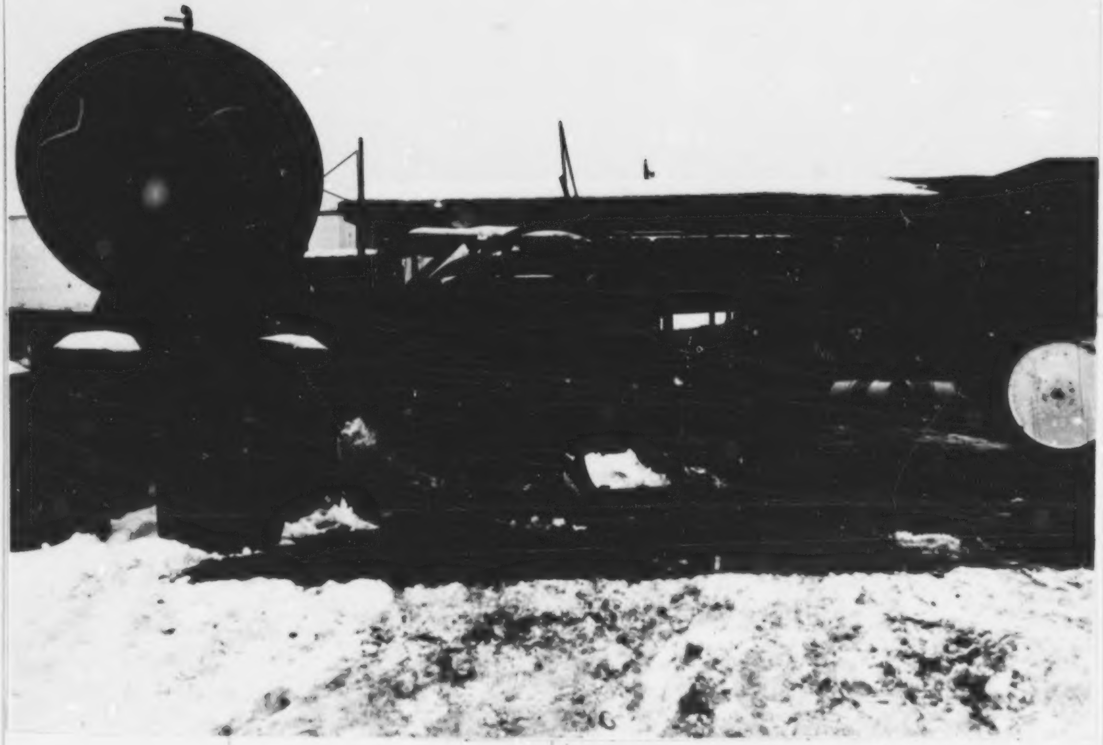

Figure 4. Chaining Machine

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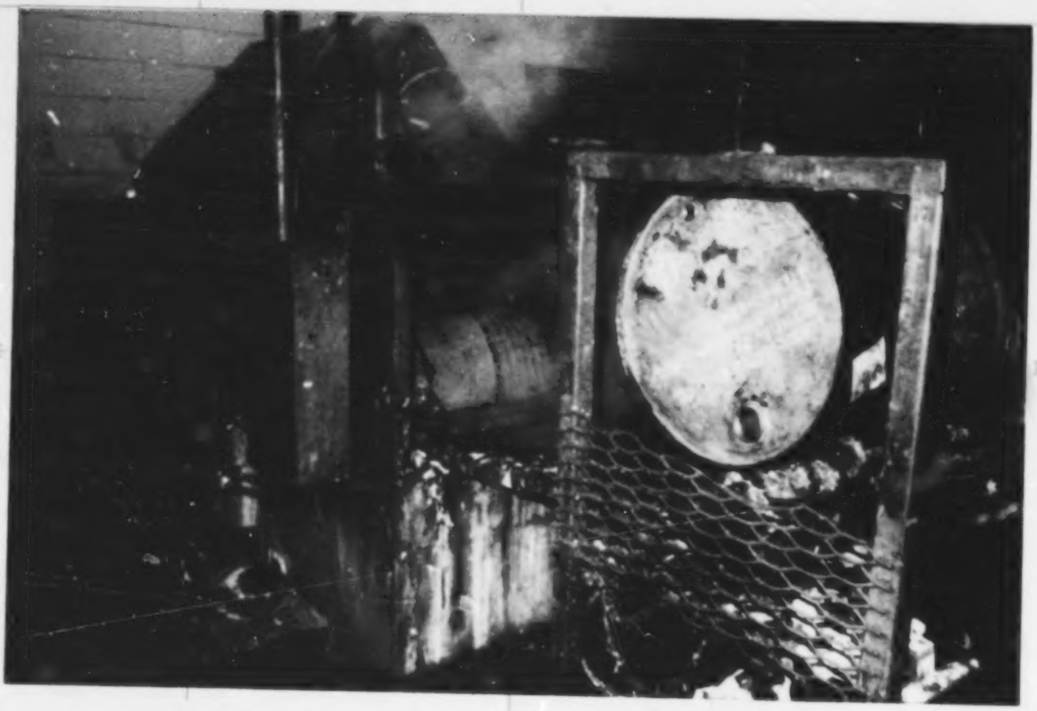

Figure 5. Caustic Submerger Tank

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chime seal, and leak test before shot blasting as shown in Figure 2. Others chime seal and leak test after shot blasting. After the caustic and acid rinses, drums are dried using vacuum siphons.

Dedenting with tight head drums is done using compressed air: 560 kPa (80 psi) pressure is used for 18 gage drums, and 280 kPa (40 psi) for 20 gage. Figure 6 shows a photograph of a dedenter. It is essential for worker safety that the drum be shielded during dedenting. Weak drums occasionally rupture explosively upon applicaton of compressed air.

Because the most frequent kinds of leaks are those around the bottom chime, and because handling and shipping often cause the drums to become out-of-round, the bottom chime is sealed on all reconditioned drums. Figure 7 is a photograph of a typical chime sealer.

Leak testing is an operation critical to maintaining product quality control. Several methods are used. 1) Leak testing is done by inserting an expandable plug connected to a compressed air line into the 5-cm (2-inch) bung hole. The 2-cm (3/4-inch) bung hole has a fitting in-place. After the plug is inserted, a star wheel rotates to hold the drum completely submberged for about 5 seconds while about 7 pounds of internal pressure are maintained within the drum. 2) The drum is pressurized with an air hose in the 2-cm (3/4-inch) bung hole with the 5-cm (2-inch) bung in place. The drum then rotates under a soap spray. 3) The drum is pressurized to 49 to 56 kPa (7 to 8 psi), and an air valve is closed behind an air gauge. The operator checks the gauge for a pressure drop. 4) In some cases CO_2 is used to pressurize the drum. Figure 8 shows a picture of a leak tester. If leaks are found, the testing operator removes the drum from the processing line and it then is repaired or discarded.

During shot blasting, small steel shot is used to abrade the drum exterior. Shot blasting serves two purposes: 1) it cleans the outside of the drum, removing residual paint, labels, or caustic, and 2) it prepares the surface for painting. Paint adheres better to rough drum surfaces. In fact, some reconditioners use steel buffing to prepare surfaces for painting. Usually this is done by some of the 38 percent of reconditioners who do not use shot blasting. Figure 9 shows a shot blaster.

Some reconditioners preheat drums before painting in order to improve finish quality. After painting, about half of the facilities bake the paint. Upon inspection and placement of final fittings, the drums are ready to be shipped.

This process flow description, while not exact for any particular plant, is a fair representation of a typical washing facility.

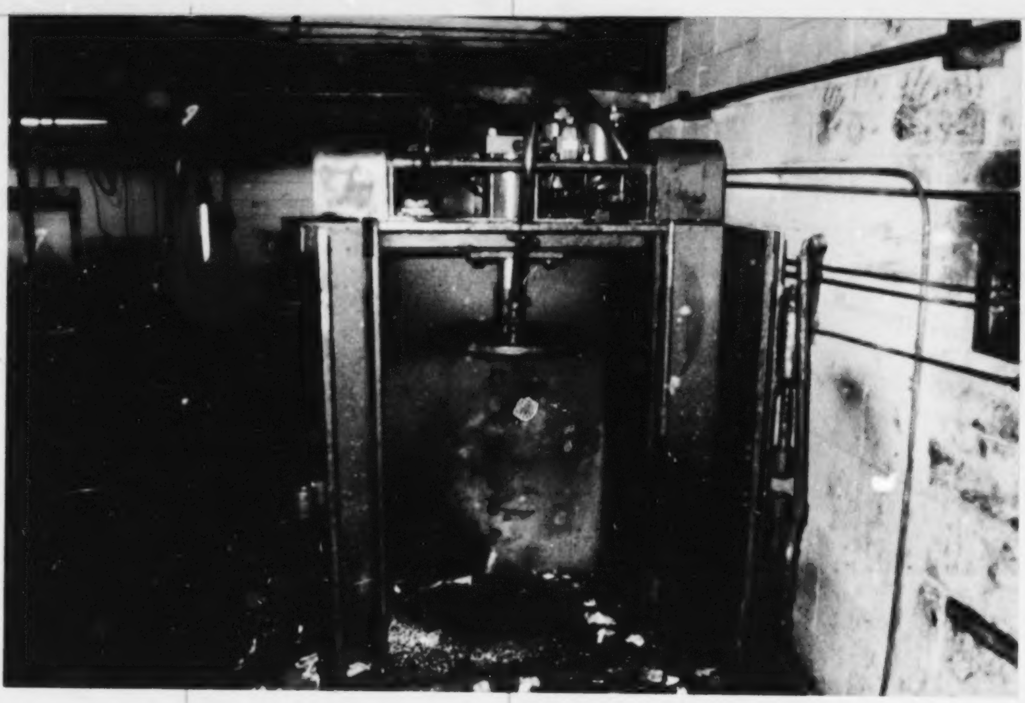

Figure 6. Tight Head Dedenter

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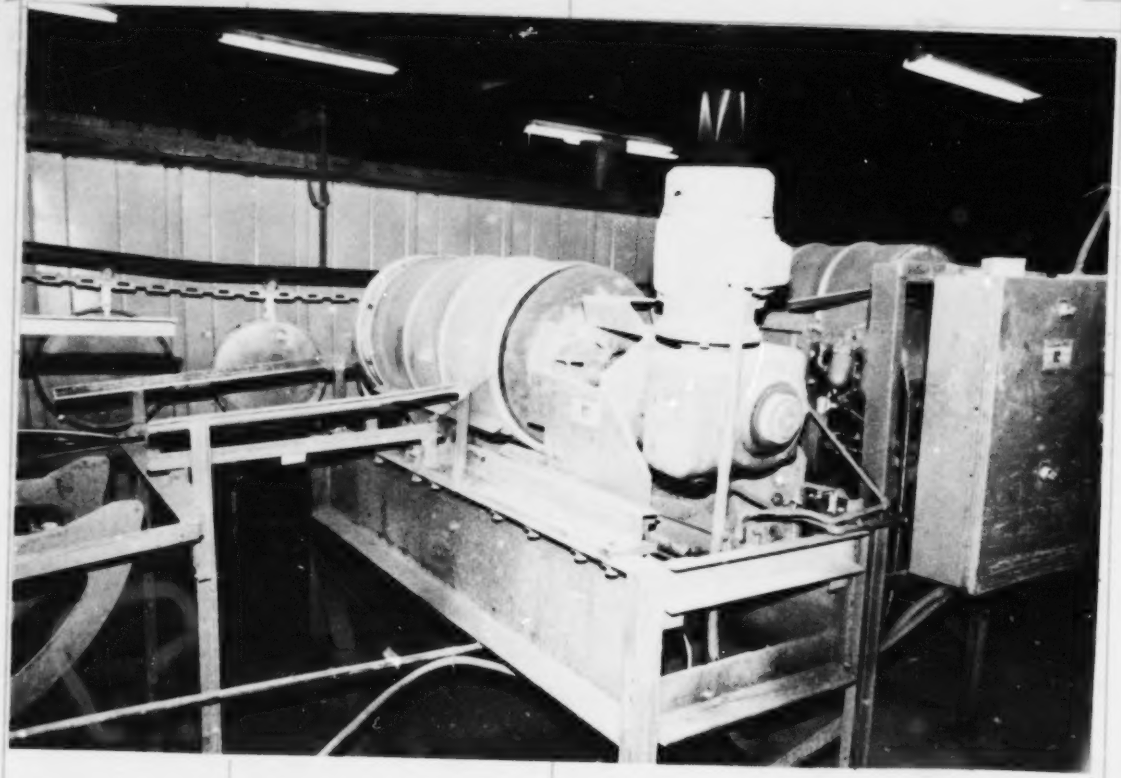

Figure 7. Chime Sealer

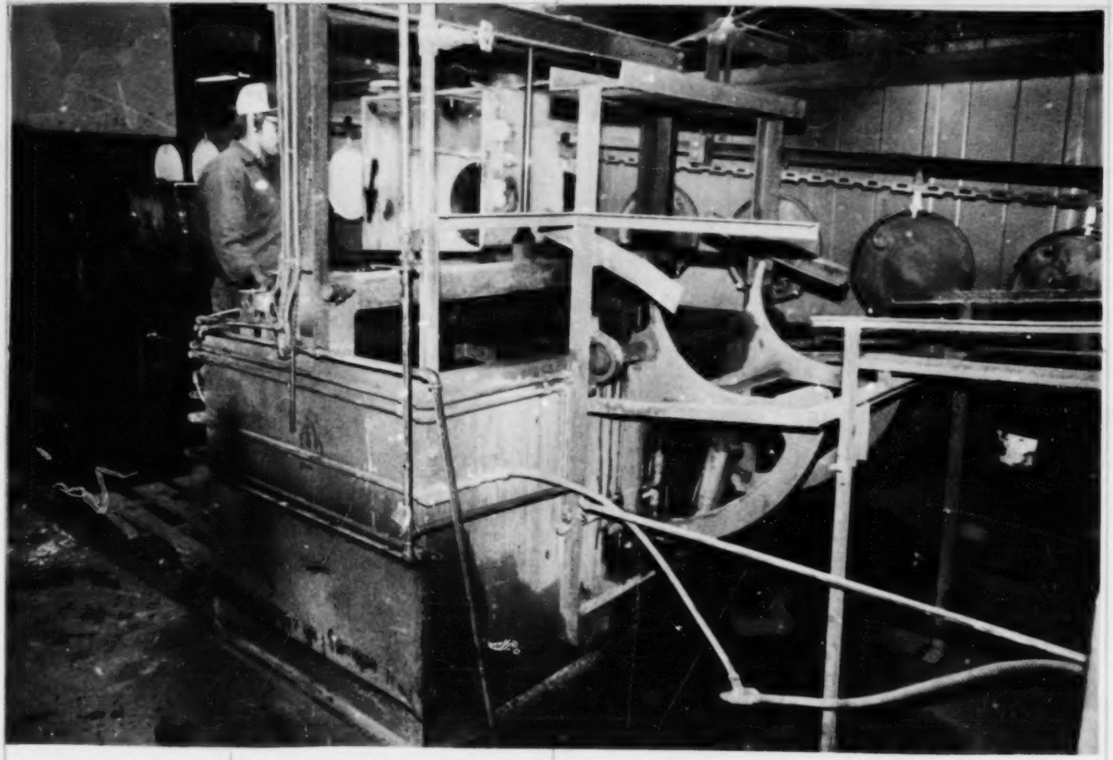

Figure 8. Leak Tester

Figure 9. Shot Blaster

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Water used and thus wastewater generated during processing historically has been in the 114 to 189 liters/drum (30 to 50 gallons/drum) range. In some cases, amounts up to 379 liters/drum (100 gallons/drum) have been observed. Water use rates of 38 liters/drum (10 gallons/drum) have been achieved at a number of plants. Many reconditioners believe that 38 liters/drum (10 gallons/drum) should be an objective for all washing operations. In 1975, Japanese reconditioners averaged about 102 liters/drum (27 gallons/drum). Many washing facilities have moved to complete recycle systems, and more are expected to do so soon.

Burning Process

The description for burning pertains to a continuous tunnel furnace operation, although there are close similarities between the process train at batch and continuous furnace plants. Figure 10 shows a flow diagram for a burning facility. Such plants have fewer unit operations than washing plants. Also there tends to be less variation between burning plants than for washing facilities.

Figure 11 shows a diagram of a typical furnace with an afterburner. A photograph of a continuous tunnel furnace is shown in Figure 12.

At most plants drums are inspected upon receipt, and those containing residues beyond plant criterion for emptiness and those containing unacceptable materials are returned to the shipper along with damaged drums. Some reconditioners drain the drums before burning in order to reduce temperature excursions due to materials in the drum. Others believe that the best way to get rid of the residuals in the drum is to burn them directly; thus, draining before burning is avoided.

Some furnaces have water sprays or steam injection at the inlet opening to prevent flashbacks, and hence possible operator injury. Others have built-in distance barriers to reduce operator exposure to flashbacks.

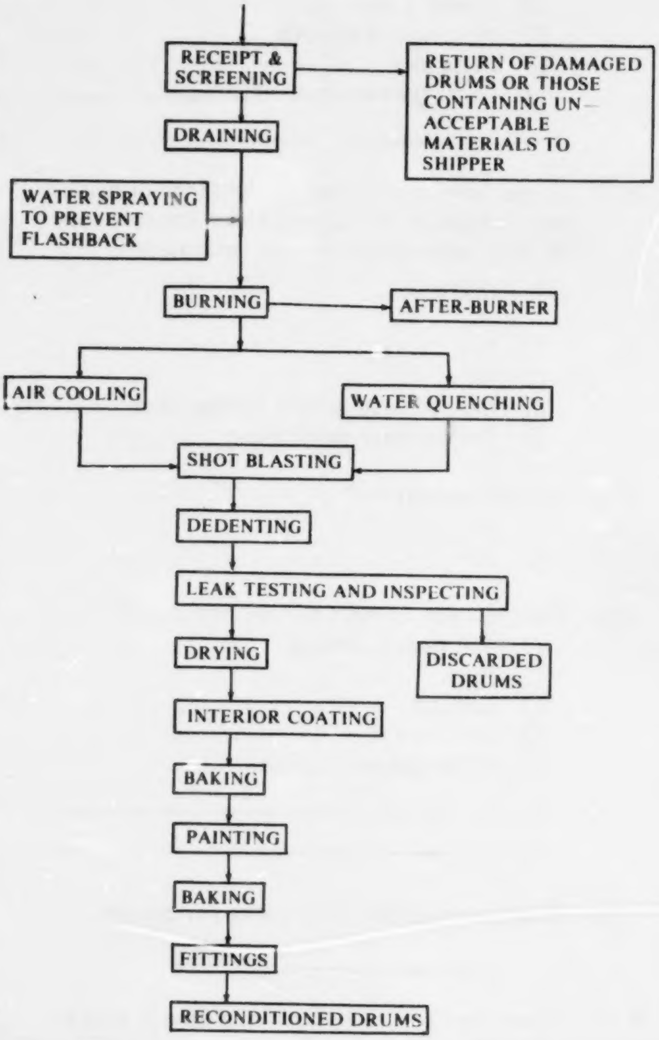
Operating and design criteria for burning facilities will be discussed later in this section. All burning plants have afterburners. Some are in operation all the time, but most are designed to operate only when an opacity detector signals that particulates are in the furnace emission.

When drums exit the furnace, they are either air-cooled or water quenched. About 40 percent of burning plants have the capability to quench, but not all use it all the time. Some only operate the water quencher when smoky drums are being burned, or when there is a visible emission from the drum outlet opening.

The next two operations are shot blasting and dedenting, in

FIGURE 10

BURNING FLOW DIAGRAM


RECEIPT & SCREENING
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DRAINING
WATER SPRAYING TO PREVENT FLASHBACK
BURNING
AFTER-BURNER
AIR COOLING
WATER QUENCHING
SHOT BLASTING
DEDENTING
LEAK TESTING AND INSPECTING
DRYING
DISCARDED DRUMS
INTERIOR COATING
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RECONDITIONED DRUMS

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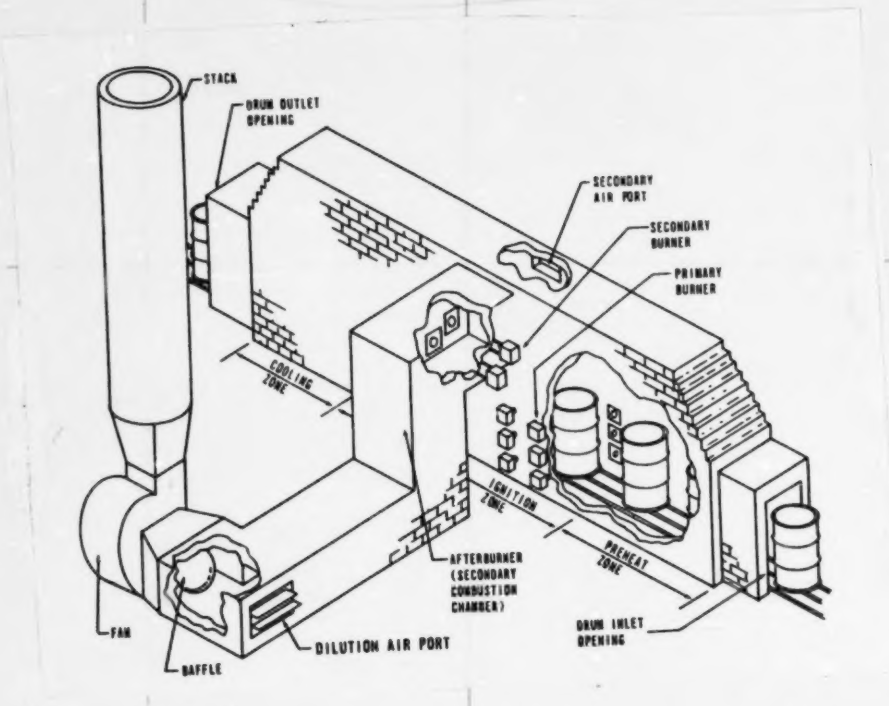
STACK
DRUM OUTLET OPENING
SECONDARY AIR PORT
SECONDARY BURNER
PRIMARY BURNER
COOLING ZONE
IGNITION ZONE
PREHEAT ZONE
AFTERBURNER (SECONDARY COMBUSTION CHAMBER)
DRUM INLET OPENING
DILUTION AIR PORT
FAN
BAFFLE

FIGURE 11

DIAGRAM OF FURNACE WITH AFTERBURNER

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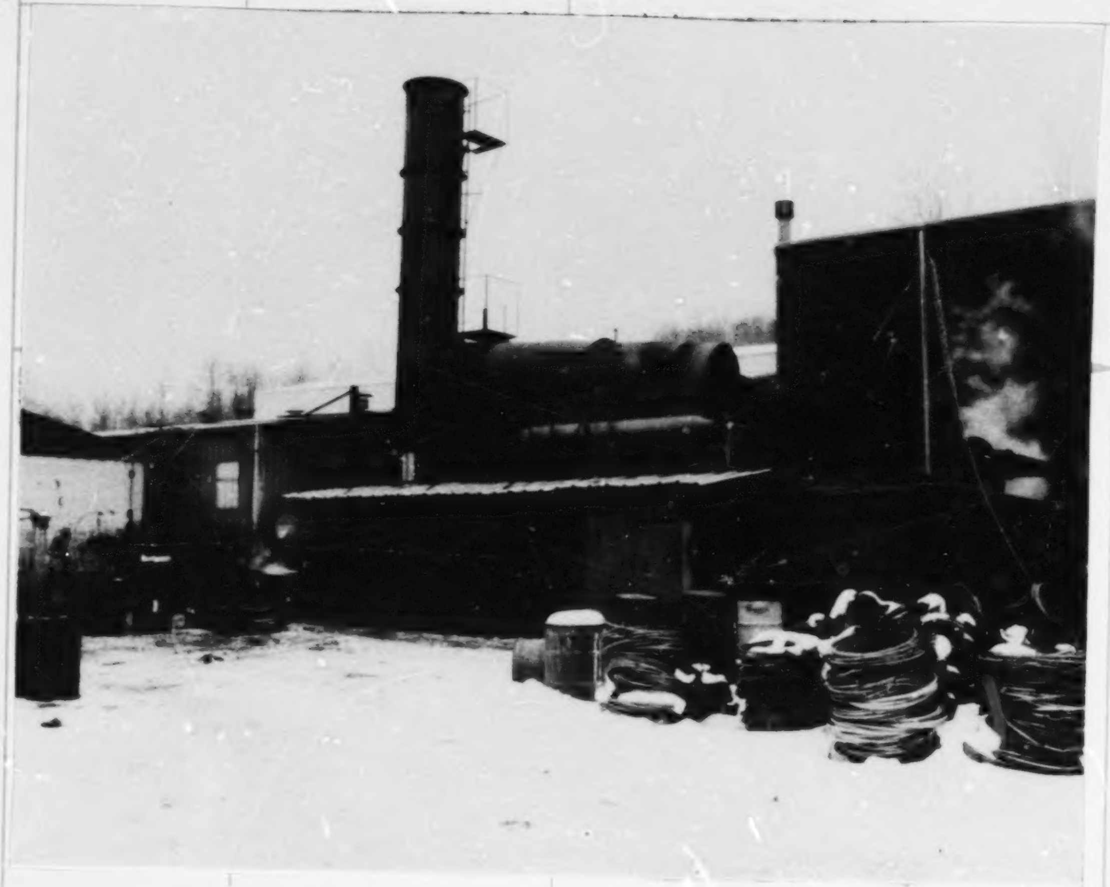

Figure 12. Furnace and Afterburner

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either order. Shot blasting is essentially the same as for washing plants except that burned drums (open head) are shot blasted inside and out. Dedenting is different for burning operations than in washing plants. Open head drums are dedented mechanically with an expander dedenter (See Figure 13).

In some plants, dust from shot blasting is removed by vibration, and by a washing step in others. A few plants incorporate a step wherein rust inhibitor is applied in water spray. This is not done when the drum is intended to have an interior liner.

After shot blasting and dedenting, the bottom chime is sealed on a chime roller. Then the drum is leak tested and inspected. Leak testing is similar to that done for tight head drums except instead of an expandable plug for a bung hole, a cap for the entire head is used. When leaks are detected, the drums are set aside for repair or discard.

After drying, drums receive an interior coating (epoxy and phenolic linings) and the outside is painted. These finishes usually are baked on, sometimes at the same time. Effective use of heat is made in some instances where the first bake for the interior coating is the preheat for the painting booth.

Upon placement of the lid and ring, the drum is ready to be shipped.

OPERATING AND DESIGN CRITERIA

Washing Process

Caustic Solutions--

Reconditioners during plant visits almost universally reported that sodium hydroxide (caustic) stripping solutions work best in the 12 to 15 percent concentration range and at temperatures from 82°C to 93°C (180°F to 200°F). The NABADA questionnaire generally confirmed these operating ranges as being representative of mean conditions. However, variations between reconditioners is significant.

For preflushing, the mean caustic solution concentration is 12.2 percent with a standard deviation of 6.9 percent caustic. Of 26 data points, the minimum is 4 percent and the maximum is 40. Mean preflush temperature is 82°C (180°F) (standard deviation - 13°C or 23°F). As expected the caustic stripper wash is more concentrated and has a higher temperature; but, not significantly so. Mean caustic stripper solution is 13.4 percent (standard deviation - 8.5), and mean temperature is 84°C (184°F) (standard deviation - 13°C or 24°F).

A common rule employed by reconditioners is to use one pound of caustic per gallon in making up or rejuvenating a

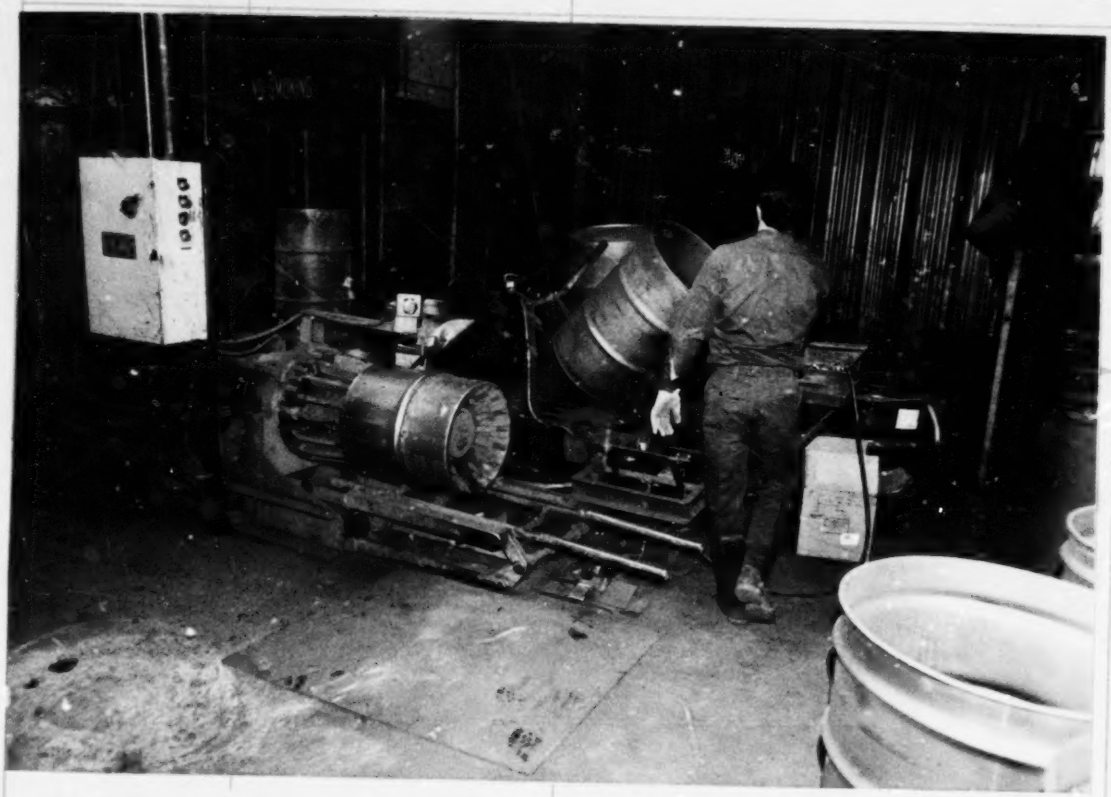

Figure 13. Open Head Dedenter

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caustic bath. This of course calculates to be 12 percent by weight.

Caustic strength is measured in two ways. First, plants periodically run acid titrations to check on the solution strength. Second, experienced reconditioners closely monitor finished drum surface quality. When drums are not cleaned as well as desired, solution strength is boosted.

Caustic solutions usually are heated by steam injection or steam coils from central plant boilers. Rarely is waste heat from furnaces or afterburners used to heat these solutions. One reconditioner insulated preflush and stripper tanks in order to conserve heat.

Recycle and reuse of caustic solutions will be discussed later in the section on pollution control practices.

A manufacturer claims to have developed an "activator" which enhances the performance of caustic washing. The additive supposedly reduced the time to flush acrylic enamel paint from a drum from 16 to 6 minutes. Conditions required for effective use are caustic strength of 12 to 15 percent, and temperatures greater than 82°C (180°F). About 5.7 liters (1½ gallons) of additive are required for 19 liters (5 gallons) of caustic solution. The manufacturer reports the cost per drum for the additive is 6 cents.

Chaining--

Nearly 88 percent of all washing plants chain some drums. It is presumed that the rest do not because they receive only "easy-to-wash" drums, e.g. oil and solvents. The average washing facility claiming to chain drums actually chains about 22 percent of all drums received. Total range is from 1 to 100 percent.

Acid Wash--

Only about 37.5 percent of washing plants use an acid wash. Essentially all that do, use hydrochloric at 20° Baume (approximately 32 percent). One plant reportedly used 12 Molar reagent grade hydrochloric acid (38 percent HCl).

Dedenter--

Reconditioners customarily recommend dedenting of tight head drums at a pressure of 490 kPa (70 psi). In the NABADA survey, 35 plants reported mean pressure of 455 kPa (65 psi); however, the standard deviation was nearly 30 percent of the mean (133 kPa or 19 psi). The range was 56 to 840 kPa (8 to 120 psi). Five plants reportedly dedented tight head drums mechanically. The exact method was not specified.

Leak Tester--

Recommended industry practice for leak testing pressure is

49 kPa (7 psi). Nearly 60 percent of the plants use exactly that amount; others choose to use slightly higher pressures. In fact, the mean for the NABADA survey was 56 kPa (8.0 psi) (standard deviation - 12 kPa or 1.7 psi).

Shot Blaster--

For those NABADA members who responded to the association questionnaire, drum rates through the shot blaster ranged from 50 to 450 drums/hr. The time per shot blasting cycle ranged from 8 to 20 seconds. All were on automatic timers. A typical time for processing through a shot blaster is illustrated at one plant where it takes 3 seconds to load; 18 seconds to blast; 3 seconds to unload; and 5 seconds to reset. Shot blasting rate is dependent upon the number of wheels in the blaster and their developed horsepower. Examples of blasters described by NABADA responders are as follows: a blaster used to process 450 drums/hr has four wheels, three at 11 kw (15 HP) and one at 15 kw (20 HP); a large plant has six shot blasters, two 4-wheel, two 1-wheel, one 2-wheel, and one 10-wheel. The 10-wheel shot blaster has a 15 kw (20 HP) motor on each wheel; however, only eight wheels are used at full capacity, and two wheels at half capacity.

Rollers which move drums through the blaster are rubber-covered. Typical output volume of exhaust gas from a small (50 to 60 drums/hr) shot blaster is 100 ACFM at 149°C (300°F).

Water Usage--

Responders to the NABADA questionnaire indicated that water use rate per drum is 66 liters/drum (17.5 gallons/drum). This is for plants that wash, burn, or both. For plants that washed only, the use rate was 50 liters/drum (13.3 gallons/drum). Plants that only burned had a rate of 41 liters/drum (10.9 gallons/drum). The conclusion is interesting in that washing plants use more water than burning plants, as expected, but not appreciably more. Another conclusion is that facilities that perform both functions use more water than those that do only one. Finally, it may be concluded that the reuse potential in drum reconditioning is yet to be realized. If caustic washing per drum requires 38 liters (10 gallons), and this comes from a caustic reservoir, there can be much more effective use of recycling.

Automated Washing--

In an effort to reduce labor operations at larger washing plants, automated processing has been installed at several plants. The most popular automated system is that built by Richmond Machine Company of Philadelphia - the "Flushomatic". Currently, there are eleven being used by those that responded to the NABADA questionnaire. The largest in operation is at the Acme Barrel Company in Chicago. At Acme, all drums are preflushed at least once before entering the Flushomatic. The machine has 30 cleaning stations with five drums proceeding through abreast; hence, 150 drums are in the unit at the same time. Progression and indexing rate is eight per minute. The 30 stations are: one detergent wash, one caustic wash, 12 drain stations, two hot water rinses, five acid washes, two cold water rinses, two siphon stations, four drying stations, and one inspection station. These are not necessarily in sequence.

Some reconditioners believe that the acid wash is an essential step in providing a clean drum. Only in this way, they claim, are organics completely removed. Because of the rapid movement of drums through the machine, reconditioners use hot hydrochloric acid (12 percent at 60°C or 140°F). The primary reason for the acid wash is rust removal. The acid environment dictates use of special corrosion-resistant minerals.

Sodium nitrite is used as a rust inhibitor. Hot air drying takes place at 816°C to 871°C (1,500 to 1,600°F). Care must be taken to avoid entrainment of combustion products in the hot air stream and subsequent deposition on drum interior surfaces. Main disadvantages of automated washing are: poor drying, requirement for a skilled electrician for maintenance, and rapid nozzle deterioration. The advantage is greatly reduced labor requirements.

Burning Process

Operating and design criteria for drum burning furnaces rely heavily on guidelines described by Los Angeles County in the Air Pollution Engineering Manual (8). Drum reclamation furnace designers commonly model their approaches upon the Los Angeles example design. An article by Papenhuyzen (9) is a Canadian supplement to the basic Los Angeles approach. These primary sources recently were augmented by issuance of NABADA drum reclamation furnace standards of design and operation (10). Purpose of the NABADA standards is "...to provide uniform methods and procedures for design, construction, operation and maintenance of drum reclamation furnaces of the type commonly used in the drum reconditioning industry."

Each of these major references, especially the Los Angeles example, along with specific plant experience, serve as the basis for this part of the section.

Criteria for batch furnaces will be discussed briefly. Then the remainder of this part will focus on continuous tunnel furnace operating and design criteria.

Batch Furnaces--

The batch furnace burning chamber is designed to hold one 208-liter (55-gallon) drum with about six inches clearance between the drum and refractory walls. The drum, which is burned upside down, has gas burners arranged around it so that it is completely enveloped with flame. Burners operate at 20 percent excess combustion air, which enters through ports on the chamber sides. Air ports should be designed to permit induction of 200 percent excess air to provide for combustion of an assumed 1.8 kg (4 pounds) of combustible materials during a 4-minute residence time. The burning properties of the combustible materials are assumed to be equivalent to US Grade 6 fuel oil (residual fuel). Burners should be able to maintain temperature of the induced air at 538°C (1000°F) and the drum at least 482°C (900°F).

Continuous Tunnel Furnaces--

Most information on drum reclamation furnaces is for continuous tunnel type. Batch-type furnaces are rarely used in larger burning plants. Batch operations simply do not have economical production rates at high volumes. Because of the common and well-known sources of design information for continuous tunnel furnaces, most such furnaces are very similar.

Preflushing and Purging--

Some reconditioners believe that preflushing of drums is crucial to effective and well-controlled burning. They maintain that the most difficult aspect of burning is temperature control, and large or fluctuating amounts of combustible residuals exacerbate an already tough problem. Preflushing minimizes variations in combustible material amounts, and serves to prevent flaring, flashbacks, and other temperature excursions. Conversely, others hold that preflushing only increases the sludge problem faced by all reconditioners. They would prefer to deal with furnace control problems rather than pay for added sludge disposal in secured disposal sites. In the latter approach there could be damage to furnaces, risks of air pollution violations increase, and the problem of sludge disposal still remains even though volumes are reduced.

Drums are placed inverted on the conveyor into the furnace tunnel. This permits residue to soften, melt, and drip out as it proceeds into the preheat zone. Inverted drums are less likely to be deformed at high temperatures in the vertical position than horizontal. Another advantage of the inverted vertical position is that the burner flames can be focused on the bottom chime where most of the residue is located and at the same time be as far from the conveyor as possible.

The principal disadvantage of the inverted position is that combustion gases may be trapped inside the drums. Papenhuyzen (10) solved this problem by locating two air jets directly below the conveyor: one in the ignition zone and one in the cooling zone. The jets blow upward continuously, thus purging each drum twice.

Combustible Materials--

All references of importance (8)(9)(10) use the same assumptions for designing for combustible contents. Burning properties of combustible materials are assumed to be equivalent to

US Grade 6 fuel oil (residual fuel). This assumption is for average design conditions; however, actual burning properties can vary significantly. Customarily furnace designers use an average value of 1.8 kg (4 pounds). The combustible content of residual materials varies widely; however, Los Angeles County stated that 90 percent of all drums as received for processing contain from zero to 1.8 kg (4 pounds). Actual drum residue behaves differently and unless safeguards are designed into the system some drums will preignite explosively ahead of the ignition zone, while difficult to burn materials, like rubber gaskets, will burn long after dragout by the conveyor.

Furnace Configuration--

Figure 11 shows a typical furnace with an afterburner. The furnace is divided into three zones. First is a preheat zone where the drums are heated by radiation from ignition further down the tunnel. This zone helps to shield operators from the intense heat of the ignition zone. Typically, residues or sludges soften and drop out within 20 seconds after entering the furnace, and hence in the preheat zone. The second is the ignition zone where primary burning takes place. Combustion gases exit through the top of this zone into the afterburner. The third zone is for cooling where a small amount of burning completes combustion. Drums are cooled by induced air in this zone. Preheat and cooling zones conserve heat in the tunnel.

Conveyor and Ash Handling--

There is some variation in conveyor and ash handling systems. Normally, conveyors are drag-type wherein residues drip through the conveyor belt onto the tunnel floor and are dragged into the ignition zone by bottom angle flights. Conveyors are driven by gearhead motors with heat-resistant alloy or water-cooled bearings. Types of conveyors include special alloy chains with scrapers and stainless steel flat wire belts. One plant uses a vibrating conveyor to turn the drum and achieve more even heating.

Sometimes instead of having a flight of angle belt guides for scraping residue through the bottom of the tunnel, other methods are used. For example, one method burns leakage using a tray under the chain and behind the sprocket.

Usually, the conveyor return is beneath the tunnel refractory floor. Belt tension for stainless steel belt conveyors can be maintained over varying temperatures using air cylinders to push against the pivoted frame of the tail shaft.

Drum ash is scraped into an ashpit, which can have clean-out doors. Also, water quenching may be used for 1) drum cooling, 2) smoke suppression, and 3) evaporation to maintain zero discharge.

Residence Time--

The minimum residence time in the ignition and burning zones is 4 minutes (10). This time should be increased to prevent smoldering of difficult or slowly burning materials which may be dragged out on the conveyor, adhering to the drum, or scraped from the furnace floor. In some cases, slowly burning materials may not be combusted entirely even at 12 minutes retention time. Design of residence time is influenced by whether provisions has been made for dragout quenching.

In the NABADA survey, 27 burning plants reported an average residence time of 6.6 minutes. Only one plant had a residence time of less than 4 minutes.

Furnace Sizing--

Tunnel--Dimensions of the tunnel are controlled by the size of a typical 208 liter (55-gallon)drum. Drums average 61 cm (24 inches) diameter and 89 cm (35 inches) in height. For 114 liter (30-gallon) drums, diameter and height are 48 and 74 cm (19 and 29 inches), respectively. Usually 2.5 to 5.0 cm (1 to 2 inches) clearance is provided between the 208 liter (55-gallon) drum and the walls and arch of the refractory-lined opening. Therefore, typical internal dimensions are 66 cm (26 inches) wide by 93 cm (36.5 inches) high. In practice, one drum should be in position to minimize drum inlet and outlet openings thus maximizing in-draft velocities of combustion air. About 90 cm^2 (14 square inches) of space is provided at each opening for the conveyor.

Length--Furnace length is determined in two ways. The first, based upon the desired production rate, is the most common way. The second method is based on the burner flame pattern. Production rate calculations are simple. The length is the product of production rate times drum spacing times residence time divided by the operating factor. The ratio of actual production rate to theoretical design production rate is the operating factor. Each facility should establish its own operating factor. The bases should be past performance, maintenance program effectiveness, production scheduling, and other processing operations. As noted by the NABADA standard (10), entrance and exit vestibules must be added to the calculated length to determine overall length.

Spacing must not be less than 7.6 to 10.2 cm (3 to 4 inches), otherwise flames will not completely cover drum exterior surfaces. Design spacing should be 12.9 to 15.2 cm (5 to 6 inches).

For an example calculation (in English units), assume that the desired actual production rate is 300 drums/hr, drum spacing is 2.5 feet (2 feet for the drum and six inches between drums), residence time is 4 minutes, and the operating factor is 75 percent. Hence, the length is:

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$$\frac{300 \text{ drums/hr} \times 2.5 \text{ feet} \times 0.067 \text{ hr}}{0.75} = 66\text{-}2/3 \text{ feet}$$

The volume of the ignition zone can be determined using a heat release factor of 6.8 x 10^8 joule/hr/m^3 (22,000 BTU/hr/ft^3). Thus, if burner flame patterns dictate dimensions such as 1.1 meters (3.75 feet) for height and width, then length can be back-calculated.

Drum rates in the NABADA survey varied from a low average of 354 drums/hr to a high average of 486 drums/hr. Furnace lengths averaged 13.6 meters (44.6 feet) for burning plants surveyed.

Temperature--

Furnace temperature must be high enough to combust all organic materials, but not too high as to cause drum warpage or scaling. Typical temperatures are 482°C (900°F) for the drum and 538°C (1000°F) for effluent air temperature. NABADA standards recommend temperatures not to exceed 649°C (1200°F). However, a Los Angeles reconditioner claims that 732°C (1350°F) has been maintained in the primary ignition chamber without drum distortion.

In the NABADA survey, the mean furnace temperature was 677°C (1250°F) (standard deviation - 153°C or 276°F) for 26 burning plants. Range was 316°C to 982°C (600°F to 1800°F). These most likely are exhaust gas temperatures and do not represent drum temperatures which are lower.

Drum temperatures can be judged visually to some extent. Drums glow dull red at about 482°C (900°F), and reach bright orange at about 538°C (1000°F). Beyond 538°C (1000°F) the drums can become distorted, warped, scaled, flaked, and thus lose strength.

Burner Configuration--

Burners are mounted in refractory walls 15.2 cm (6 inches) from the sides of 208-liter (55-gallon) drums. Hence, the width of the tunnel in the ignition zone is 0.9 meters (3 feet). Only this zone contains burners. The NABADA survey determined that burning nozzles spanned an average length of 4.1 meters (13.5 feet) or about 30 percent of the furnace length.

Burners often are arranged in eight vertical rows of two or three burners with four rows on each side of the chamber. Spacing of the burners is from 0.6 to 0.8 meters (2 to 2.5 feet). The rows are offset about half the spacing distance on opposite sides of the chamber. This prevents the flames from opposing each other.

At least two rows are required to cover the drum. The top row focuses on the chime, while the bottom is about 15.2 cm (6 inches) above the conveyor. If there are three levels, the burners are mounted about 30.5 cm (12 inches) apart. The first row of burners usually are set at maximum capacity. Succeeding rows either are adjusted manually to lesser amounts, or are controlled by a thermocouple at afterburner inlet.

Afterburner--

All reconditioners who burn have afterburners. Because the afterburners need only operate when there are particulate emissions from the furnace, opacity detectors signal the afterburner when to turn on and off. In practice, afterburners are on all the time at more than 80 percent of burning plants. For all plants, afterburners operate about 95 percent of the time.

The NABADA survey showed that the average afterburner operating temperature is 810°C (1490°F). About 20 percent of the plants operated afterburners at less than 760°C (1400°F), some as low as 316°C (600°F). Failure to operate at least at 760°C (1400°F) would appear to be a waste of money.

Los Angeles County (8) recommends temperatures of at least 760°C (1400°F) and minimum residence time of 0.5 second. (California requires reconditioners who burn pesticide drums to maintain afterburner temperatures at 890°C or 1650°F.) It is believed that these conditions will insure complete conbustion of most organic contaminants. Average gas velocities of 6.1 to 9.1 m/sec (20 to 30 ft/sec), and secondary air ports providing 100 percent theoretical combustion air are recommended (8).

The NABADA standards (10) are different in a few respects. Although NABADA recommends a 0.5 second residence time, 50 percent excess air is recommended. Calculation of afterburner chamber size is based on the maximum weight of combustibles introduced into a furnace over a fixed time period. An allowance of 3 minutes is the most widely used number. Good mixing of smoke and gases with afterburner flames and secondary combustion air is essential.

Draft--

Draft alternatives include natural draft, induced draft fan, or forced air fan. Induced draft or forced air fans are preferred, because of greater uniformity. Cost-effective systems are induced draft fans with heat slingers where combustion gases are cooled to less than 427°C (800°F) by air dilution.

Fuel--

Natural gas is preferred in drum burning furnaces. Where gas is uneconomical or unavailable No. 2 oil is recommended.

Operating Methods and Controls--

Operation of a drum reclamation furnace depends heavily upon the judgment and skill of the operator. If black exhaust smoke is observed, this may indicate a lack of combustion air or overloading of the afterburner. White smoke is indicative of low afterburner temperatures. This latter problem can be controlled by reducing combustion air or increasing fuel to secondary burners.

In the NABADA survey, nearly 81 percent of drum burners said they varied drum rates to control emissions. This variation can take several forms: 1) use a variable speed conveyor to slow down processing when it appears that combustion capacity may be exceeded; 2) use variable spacing of drums to accomplish the same purpose; and 3) mix or blend "hot" and "cold" drums to cause the same effect as variable spacing without slowing down production.

Other methods include controlling primary chamber and afterburner temperatures by modulating type automatic temperature controllers, and use of auxiliary gas or oil burners. Additionally, secondary combustion air can be provided to the afterburner to achieve complete combustion. Flow of secondary air should be reduced using monitor/controllers in order to conserve fuel during periods when clean drums are being processed.

Papenhuyzen (9) designed an electric interlock system to prevent drums from being fed into the furnace before attainment of operating temperature. The interlock system made the conveyor inoperative until 538°C (1000°F) was reached in the ignition zone, and 871°C (1600°F) in the afterburner.

Construction Materials--

Exterior walls of furnaces usually are 6.4 mm (¼-inch) steel plate. This thickness helps to prevent warping and buckling, and permits a large allowance for corrosion. The shell or outer case is separated from the refractory brick by 6.4 cm (2.5 inches) or more of air cooling space or metal wool insulating material having a service temperature of at least 1093°C (2000°F). Design skin temperature is 121°C (250°F) maximum.

Refractory brick materials include carborundum brick (5-year life) or 23 cm (9 inches) of superduty firebrick or plastic refractory. Other less severely heated areas may be lined with 23 cm (9 inches) of high-heat-duty firebrick or ASTM Class 27 castable refractory.

The furnace fan should have a service rating of 649°C (1200°F). It would be appropriate to use stainless steel for conveyor support bars, and drum guide bars in the ignition zone.

Waste Heat Utilization--

The considerable heat emanating from the burning plant stack can be used in several beneficial ways. Several plants in the U.S. and Japan use heat exchangers to make steam for plant heating and caustic solutions at companion washing plants. Heat can be employed to preheat drums for purposes of enhancing drainage. Also heat could be used for heat drying of wet drums or for input into baking ovens.

PROCESSING PROCEDURES

The nature of the drum reconditioning industry is such that production of high quality reconditioned drums, maintenance of environmental quality, and protection of worker well-being are interrelated. As a result, the industry has used a number of processing and management procedures to aid in attaining objectives in each of these areas. Some of these procedures are described below.

Drum Restrictions

Nearly all (about 96 percent) reconditioners claim to refuse to accept certain types of drums for processing. Yet less than 10 percent have written policies or instructions for their customers. However, based upon recent RCRA regulations, this figure is expected to increase. Several leaders of the industry have emphasized that policing of incoming drums is extremely important; however, even some of them are lax in informing their customers of what will or will not be accepted. Clearly, the intent of reconditioners may be to restrict acceptance of certain types of drums, but there appears to be poor execution.

Pesticide drums supposedly are refused by nearly 83 percent of reconditioners; however, a tour of drum storage areas reveals that such drums are accepted by some reconditioners, perhaps unknowingly. This emphasizes the need for stronger enforcement and management by reconditioners of their own drum restrictions.

Table 16 indicates the kinds of drums refused for processing. Results are expressed as a percentage of total companies claiming to have drum restrictions. Specific pesticides mentioned as being refused are: parathion, aldrin, dieldrin, endrin, lannate, DDT, malathion, dioxin, toxaphene.

Some companies have given considerable thought not only to the types of drums refused, but also to the way in which this information is conveyed to their customers. One example is a straight-forward and direct one page flyer mailed to all customers by one reconditioner.

"Notice...Notice...Notice. To all our customers and our receiving department. Due to nature of the following items, we refuse to accept any of these drums for our recycling process!" This was then followed by a list of eleven specific materials or compound classes. To help avoid confusion, the reconditioner used both the brand or popular name and the proper chemical designation from Merck Index.

TABLE 16. TYPES OF DRUMS REFUSED FOR PROCESSING (expressed as percentage of companies having restrictions)

Pesticides	83.0
Ink	29.8
Adhesives	27.7
Paint	14.9
Toxic and Hazardous Materials	12.8
Mercaptans, TDI and other Unneutralized Gas Odorants	10.6
Resins	8.5
Class B Poisons	6.4
Odorous Materials	6.4
Tar/Asphalt	4.3
PCB	4.3
Cadmium Compounds	4.3

The following are 2% or less:

Delaware Drums
Heavy Drums
Plastic Inserts
Excessive Residual
Unknown Contents
Smokers
Automobile Sound Deadener
Silicone
Acrylics
Carbon Disulfide
Chlorides
Cyanides

Mercury Compounds
Sodium
Sulfur Monochloride
Zinc Compounds
Formaldehyde
Organic Phosphates
Benzidine and its Salts
Dye
Industrial Chemicals
Carcinogens
Radioactive Materials

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An excellent notice "To Our Customers" explained a potentially troublesome problem and suggested a prudent and workable solution. "As a user of reconditioned steel drums, you have long enjoyed the economic as well as the environmental benefits of this recyclable container. Today, however, the bulk of our industry is facing possible extinction due to major and nearly insurmountable obstacles caused by our concern for a clean environment and our need to watch over our energy resources.

"It is our belief that only the strongest reconditioners will survive; those with the financial ability to afford the engineering and installation costs of approved pollution and safety control methods. OUR COMPANY is an INDUSTRY LEADER in these areas.

"You are, undoubtedly, aware that one of the most difficult aspects of the pollution problem is the disposal of solid and liquid wastes. Your company, like ours, has probably encountered increasing costs and sometimes even greater difficulty, at any cost, in the disposal of these waste materials.

"A special problem that we have with companies which manufacture or use ink is that the drums become contaminated with ink on the outside. This becomes a problem whether the drums are stored in your yard or ours. Rain water run-off from these drums eventually reaches storm sewers and a small amount of ink will add color to a stream.

"The (State and Local Pollution Control Agencies) can require you to dig up, drum and landfill contaminated earth or dam the run-off and treat the water. The solution to this problem is to have the bungs reinserted in the tighthead drums and the ink wiped from the drum with thinner. The head and ring should be reassembled to the openhead drum and also cleaned. If our customers do this, we will make sure that your drums are processed, stored and handled in an environmentally safe manner. With your help and our knowledge, complete detoxification will be accomplished within the guidelines set forth by environmentally safe procedure and insure us all of a safe and pure environment."

Another type of approach is that which is legally-based. One such letter follows:
"Dear Customer:
This letter is written to confirm my telephone conversation with you on (date) in which I confirmed our continuing interest in recycling (type) drums generated at your (location) plant. In that conversation, I restated our position as detailed in our (date) letter to (name). In that letter we agreed to release (customer) of any responsibility with regard to steel drums either picked up by our trucks at (location) plant or shipped to us by rail from the (location) plant, provided that (customer) rinses the drums and tightens the drum plugs prior to shipment.

"(Reconditioner), being aware that the drums formerly contained hazardous materials, will assume full responsibility for the future disposition of these drums, thereby relieving (customer) of any liability.

"Our firm processes these drums by thoroughly cleaning them and removing all contents before they are used again. These drums are not used for any products that would be affected after they are reconditioned.

"A copy of the above mentioned letter is attached for your files. We have enjoyed doing business with (customer) and look forward to serving (customer) for many years in the future."

This same reconditioner, for another customer, used the following terms and conditions as part of an overall agreement.

1) "(Customer) agrees to offer the drums to (reconditioner) only after:
    (a) Rinsing with hot water, caustic and detergent.
    (b) Flushing with water.
    (c) Neutralizing odors.
    (d) Replacing all fittings."

2) "(Customer) agrees to indemnify, defend and save (including officers, directors, employees and agents of (reconditioner) harmless from and against any liability, expense or loss (including reasonable attorney's fees) based upon damage to, or destruction of, any property or injury to any person (including death) arising out of or attributable to the loading, handling, transportation, use, storage or sale of the Drums by (reconditioner) (including, but not limited to (reconditioner) employees, customers or agents), including consequential loss resulting from any government action."

The last two quoted sources are offered here simply as examples of what one reconditioner sent to two customers in the past. Their appropriateness, correctness, and legality may be open to question; therefore, readers should consult their own legal advisor before attempting to use or interpret similar types of materials. Recent issuance of federal regulations in conjunction with the Resource Conservation and Recovery Act could impact these quoted passages substantially.

Receiving

Some reconditioners have instructed their drivers not to pick up drums which do not have bungs or rings and lids in place, which are not empty (as defined by EPA, reconditioning company, or NABADA guidelines), which contained unacceptable materials, or which are damaged. Despite the need to train drivers and the extra time needed to view the loading of each drum, it seems more cost-effective to conduct an inspection at pickup rather than at the reconditioner's loading dock or yard. Return trips with rejected drums could thus be avoided.

Nevertheless, an inspection should be conducted upon receipt of drums at the reconditioner's facility. Functions performed by inspectors include: categorization for yard storage; designation for deheading, refusal and return, discard or scrapping, chaining, or other mode of cleaning; determination of "smokers" during burning; replacing missing bungs, lids, and rings prior to yard storage; and draining excess contents.

Several large reconditioners require that all drums be bunged up before going to yard storage. This greatly reduces the possibility of drum drainage being washed to surface or ground waters by stormwater runoff. One reconditioner has suggested charging a penalty for drums arriving without bungs or rings and lids.

Determining "smokers" on receipt, e.g. heavy grease, undercoat, or silicone drums, permits operators to space such drums before burning. Spacing helps to reduce the possibility of generating visible smoke emissions. Another effective way to reduce possible air pollution is to drain drums upon receipt. One industry leader believes that such a step is essential not only for air pollution control purposes, but also extends the life of caustic washing solutions. This same reconditioner uses a caustic preflush even for open head drums to help prevent temperature surges in the drum incinerator and flashbacks.

Storage

The ideal storage facility is one which minimizes drum deterioration and the possibility of contaminated stormwater runoff. One reconditioner has a unique situation wherein the bulk of his inventory is stored indoors in former warehouses. Most reconditioners must contend with the elements, and it is unlikely that construction of storage shelters would be cost-effective, particularly if attention was focused upon prudent yard management techniques. These techniques include: inventory management, drum capping, and runoff control.

One reconditioner exclusively uses a "first-in, first-out" (FIFO) inventory method to minimize drum deterioration. Better drums also are less likely to leak. Nearly 90 percent of drums are processed from storage using yard trucks to feed the burning and washing lines. Receiving facilities are away from the processing lines.

Categorizing drums by type and permitting easy access leads to better drum recoveries from inventory and less potential for stormwater contamination. Most reconditioners recommend that drums not be stacked upright, which increases chances for both leakage and structural damage.

As stated earlier, drum capping (replacement and tightening of bungs, lids, and rings) greatly reduces potential for stormwater contamination. Measures to reduce stormwater problems are taking on increased importance. Runoff control is becoming required for many raw drum storage areas, and in some cases a requirement for treatment of runoff is included.

Oil Recovery

Roughly two-thirds of reconditioning plants make a concerted effort to recover oil from incoming drums. Some have special siphoning machines which are used exclusively for spent oil drums (especially where oil companies represent major customers). Others merely drain drums to pits and oil holding tanks. Some try to recover oil skimmings from density separation tanks. Higher quality recovered oil can be sold to a reprocessor, and almost 40 percent of reconditioners use this route. One plant has an interesting incentive plan whereby proceeds from recovered oil sales are distributed to plant workers. At this plant oil recovery rates are excellent.

For about a quarter of the reconditioning plants, the oil is given away. Presumably, this is for lower quality oil where the give-away is a balance between selling to a reprocessor and being charged to have it hauled away to be landfilled or burned. About 25 percent of reconditioners use these latter two routes. Several plants have oily sludge hauled by contract disposal firms. One plant gives better quality oils to a reprocessor who makes number 6 boiler fuel after mixing. (Reclaimed oil has a heat value of 3,348,000 to 4,185,000 joules/liter or 12,000 to 15,000 BTU/gal, according to one equipment vendor). One plant reported being charged by a reprocessor to have its oil hauled away.

In the NABADA industry survey, 25 plants reported average oil recovery rates as about 22,712 liters/month (6,000 gallons/month). The range was from 1,136 to 238,481 liters/month (300 to 63,000 gallons/month). The extreme variation is a function of mix of drums processed, plant size, and separation equipment capabilities. Some plants reported their oil recovered as being in an emulsified form.

In order to control fate of their drums and assure recovery for reconditioning, oil companies in Australia charge users up to $13.00 (AUS) deposit for each drum.

Discarded Drums

An industry rule-of-thumb is that drum discards should be in the 4 to 5 percent range. In the NABADA survey, an average of 5.4 percent of drums having some degree of processing are discarded. For a typical plant this means about 45 drums are discarded daily. (In the United Kingdom the discard rate is in the 6 to 8 percent range, with 4 percent being regarded as good).

Table 17 shows the fate of clean and unprocessed drums. Clean drums usually are sold for either scrap or other purposes (e.g. highway construction markers, trash barrels, and floats if they are not leakers). Less than 10 percent exit the system in landfills and in other unuseful ways. Whether the clean drums are sold for scrap or other purposes depends upon the condition of the drum and the market. Some reconditioners customarily sell to scrap dealers as well as others; hence, figures in Table 17 for clean drums do not add to 100 percent. A lower percentage of unprocessed drums are sold for scrap. New RCRA regulations will make it much more difficult to dispose of unprocessed drums.

Nearly 90 percent of reconditioners who sell to scrap dealers send the drums intact, while the remainder crush them first. Roughly two-thirds of the reconditioners use their own trucks to deliver the drums to the scrap dealer. The scrap dealer comes for the drums in the other one-third of the cases. Occasionally, reconditioners will use an independent hauler to take the drums to the scrap dealer's yard.

In-plant

Waste stream segregation can make dealing with pollution control problems easier. Caustic solutions and rinse water can be recycled and reused, but it would be very difficult to reuse blended streams. Therefore, there is increasing interest in stream segregation at washing plants. Presently, about 25 percent of washing plants segregate wastewater streams.

The nature of reconditioning makes plant cleanliness a difficult and continuing task. Nevertheless, poor housekeeping and carelessness can easily make a tough problem nearly impossible to solve. Measures to improve housekeeping often involve more drainage of drum residual contents at the plant head-end. Draining and preflushing help greatly in maintaining plant cleanliness.

Careful arrangement of floor drains can help plant cleanliness as well as waste stream segregation. One washing plant working areas are almost entirely on floor grating wherein drum residue is permitted to fall to a slab beneath which is cleaned at regular intervals.

Paper labels pose a continuing problem at washing plants. At several plants labels are smeared with a commercially-available material which facilitates disintegration during washing.

TABLE 17. FATE OF DISCARDED DRUMS

FATE	TYPE Clean (%)*	 Unprocessed (%)
Landfill	2	7
Sell for scrap	76	60
Sell for other use	67	-
Return to customer	4	18
Burn	2	
foundry drums	-	4
wash first	-	4
Unspecified	-	7

* Total does not add to 100% because of sales for more than one purpose.

PESTICIDE CONTAINERS

It was very difficult in this report to obtain accurate data on numbers of pesticide containers handled by reconditioners. A survey of reconditioners in 1973 indicated that more than one million pesticide drums were handled annually by NABADA members (4). According to one question in the NABADA survey conducted in conjunction with this report, pesticide drums accounted for only about 0.5 percent of drums processed by washing or burning. This amounts to about 210,000 drums per year for all reconditioners. Day (11) claims that in the early 1970's reconditioners processed up to 5 million pesticide drums per year. These inconsistencies become more perplexing because 83 percent of reconditioners claim they will not accept any pesticide drums at all.

In the NABADA survey for this report, when 49 reconditioners were asked how many pesticide drums were processed annually, a total of about 23,000 was reported. (More than 20,000 came from just two facilities). For all reconditioners this would amount to about 62,000, assuming that the 49 reconditioners comprise 41.2 percent of NABADA membership which in turn reconditions 90 percent of all drums. Hence, even within the NABADA survey itself the range is from 62,000 to 210,000. It is likely that the latter figure is far more realistic. It probably is safe to eliminate Day's figure of 5 million as unrealistic.

Several points are evident from the above:

1) Most reconditioners claim they will not accept pesticide drums, but the figures show they do.

2) On the average, nearly 1,000 pesticide drums pass through a reconditioner's facility each year (using NABADA survey data; maybe more using other data).

3) The reasons for poor data all reflect badly upon reconditioner management practices, i.e. either they are unaware of what they receive, they do not maintain accurate records, or they were unwilling to admit they accept pesticide drums.

Regardless of the reason for poor data, it is apparent that pesticide drums pass through washing and burning facilities. The sampling and analysis program performed in conjunction with this project, and which included pesticide sampling, will be reported separately. The intent of the remainder of this section will be to discuss current practices of reconditioners which pertain to pesticide drums.

Incineration

Deheading and burning of pesticide drums generally represents safest practice for drum reconditioners. Wilkinson et al.

(12) state that "High temperature incineration is the most highly developed disposal method for pesticides as well as many other hazardous waste materials." However, even incineration is not recommended for all pesticides. Pesticides are found as wettable powders, emulsifiable concentrates, granules, and soluble salts, for example; and can be organic or organometallic. Incineration of organometallic pesticides is not recommended because they can form volatile toxic metals, metal chlorides, and metal oxides. Moreover, potentially harmful particulates may be difficult to remove from off-gases.

Wilkinson et al. (12) concluded that "Incinerator operating conditions for a 2-second retention time at or near 1000°C (1832°F) with adequate excess air appear to be sufficient for $\geq$ 99.99% destruction of the organic pesticides that have been studied to date." If incinerators are operated properly, consistently predictable results are yielded. Pesticide destruction results for the dwell time and temperature cited above, i.e. 2-seconds and 1000°C, can be matched by trading off lower temperatures and longer dwell times or vice versa. Some pesticides require less rigorous conditions. For example, Kepone and DDT are completely destroyed at 500°C (932°F) at a dwell time of 1-second, and Mirex is destroyed at 700°C (1292°F) with a 1-second dwell time. PCB's require a temperature of 1000°C (13).

In general, incineration is best for high toxicity and/or low solubility pesticides provided there are adequate combustion controls (14). In addition to the furnace and afterburners, these controls may include scrubbers and baghouses. Additionally, any process scrubber water must be treated.

Staton and Lamperton (14) showed that about 81 percent of pesticides retained as residual in steel drums are found in the chime. Based upon reconditioning experience this is entirely predictable. In fact, this is why drum furnaces are designed to focus the top burners on the drum bottom chime.

The State of California recommends that pesticide drums be burned in a furnace operating at a minimum of 1400°F (760°C) with a dwell time of five seconds. In addition, California specifies that furnace off-gases must pass through an afterburner operating at a minimum of 1650°F (900°C). Afterburner residence time is not specified. Based upon information in other references pertaining principally to pesticide incinerators, it appears that adherence to California recommendations would permit complete destruction of most pesticides.

The major question remaining unanswered is what is the effect of temperature and dwell time trade-off. Whereas 1000°C and 2-seconds are recommended for pesticide incinerators, typical dwell time for drum furnaces is four minutes with an average temperature of 1250°F (675°C). Moreover, average afterburner dwell time and temperature are 0.5-second and 1400°F (760°C), respectively. The extended period at high temperature for normal reconditioning would seem to be adequate for the small percentage of pesticide drums normally expected to be encountered; however, this conclusion remains speculative in the absence of hard data.

On the other hand, some data does exist for pesticide drums processed at a plant following California recommendations. Six 114-liter (30-gallon) drums which had contained a toxaphene emulsion were deheaded and processed through a furnace operating in a 1430 to 1500°F (775 to 815°C) range. Drums were extracted by one liter of hexane. Approximately 30 ml of the hexane solution was placed into glass tubes fitted with teflon-lined caps, and the tubes were sent to an EPA laboratory for analysis. The laboratory report stated in part: "We found traces of toxaphene in only two of the samples at very low levels. Because these preliminary samples were largely qualitative, we can only estimate that from our results, the two drums which gave positive {results} would have contained less than 1 mg (each) of toxaphene, providing the hexane rinse was adequate." Thus, these results show that toxaphene essentially was completely destroyed.

Rinsing

Day (11) maintains that the most reliable and desirable method for pesticide disposal is to rinse the containers and makeup spray mixtures from the rinse. The National Agricultural Chemicals Association (NACA) has recommended triple rinsing as an essential step toward safe pesticide container disposal (16). NACA suggests three 19-liter (5-gallon) rinses for 208-liter (55-gallon drums), and then recycle to an approved reconditioner or to a scrap melting plant.

FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) regulations spell out guidelines for acceptance and recommended procedures for storage and disposal of pesticides and pesticide containers. For Group II containers (noncombustible), FIFRA requires triple rinsing before being sent to a reconditioner. The regulations specify that the recycled containers only should be reused with pesticides of the same class as contained previously. Many reconditioners require rinsing of pesticide drums as a condition of acceptance for processing.

In the past, drum rinsate was disposed to public sewer systems. Day (11) estimated that up to 5 million gallons per year formerly were disposed in this way. Recent FIFRA, Federal Water Pollution Control Act, and RCRA requirements strictly prohibit such practice. Day (11) also reported a common method for dealing with drums containing rinsate. Reconditioners placed old drums filled with rinsate in a separate area of their disposal site and surrounded the drum with cover material. Rinsate then is absorbed by the soil as drums corrode and leak. In many cases, nothing is known about eventual pesticide fate. Because of the uncertainty of the method, many disposal site operators and governmental officials prohibit such practice.

Rinsing can be a very effective first step in drum cleaning. Staton and Lamperton (14) showed that about 78 percent of residual Phorate is removed from drums by triple rinsing, while 96 percent of Disulfoton is so removed.

Washing

Staton and Lamperton (14) maintain that chemical processing of pesticide containers is best for those with high solubility and low toxicity, and where any residue would not affect food usage. Wilkinson et al. (12) showed that of 550 commercially important pesticide active ingredients, alkaline hydrolysis is a viable choice for chemically detoxifying 167 pesticides. For 60 of this number, alkaline hydrolysis is the primary recommended method, while it is the desired alternative for the remaining 107.

Alkaline hydrolysis, using NaOH, has been shown to be capable of completely destroying organophosphorus compounds (12). In addition, carbamates, such as the pesticide carbaryl, have been shown to be degraded rapidly under strongly alkaline conditions (12). In the former case, NaOH added to malathion solutions will yield an inorganic phosphate. Other organophosphorus compounds will result in sodium salts or exhibit unspecified structural changes. The main question, as yet unresolved, relates to the potential residual toxicity of byproducts. Some potentially could be as hazardous as the original (11). Additional work is necessary in this area.

In some strong caustic solutions, certain pesticides are degraded readily. For example, in 1 N NaOH solution at 15°C, parathion has a half-life of 32 minutes, while methyl parathion has a 7.5 minute half-life. In other words, in about 5 and 1.5 hours parathion and methyl parathion would be destroyed completely, respectively.

In a comparison of triple rinsing and processing through a commercial reconditioning plant, Staton and Lamperton (14) showed that for used Phorate drums triple rinsing would remove nearly 78 percent of the residual pesticide. Caustic washing in a reconditioning plant would remove about 88 percent. Together the two methods would result in 96.7 percent removal of Phorate. Any residue remaining appears as Phorate sulfoxide. Typically, residue measured in exhaustive tests at Oregon State University resulted in about 1.27 grams per drum or about 6 mg/l for a 208-liter (55-gallon) drum (14). Most of the pesticide residue is retained in the drum chime as indicated earlier.

There appears to be a wide disparity between the ability of triple rinsing or caustic washing to clean pesticide drums. For example, triple rinsing is highly effective in decontaminating Disulfoton drums (14). Triple rinsing removes 96.0 percent of the pesticide, whereas the total for rinsing and caustic washing is 98.7 percent. On the other hand, caustic washing is far more effective than triple rinsing for 2,4D and 2,4,5-T. More than 97 percent of each is removed after rinsing using caustic solution.

The half-life of Diazinon is 21 days in a 1 percent NaOH solution. This is about the same as Phorate (14). Comparatively, the half-life of carbaryl, at similar concentrations, is 30 minutes. Although carbaryl (a carbamate) is hydrolyzed readily, chlordane is not. Carbaryl normally appears as a solid formulation. By comparison malathion usually is an emulsion.

On the basis of the foregoing it would appear that phosphorus and nitrogen-containing pesticides lend themselves to detoxification by alkaline hydrolysis. Additionally, it appears that halogen-containing pesticides are insensitive to this method. Implications of these observations were determined by evaluating production figures for major types of pesticides. For pesticides produced in quantities greater than 1000 metric tons per year in 1974, phosphorus and nitrogen-containing pesticides comprised 85.4 percent of all pesticides. The bulk of the remainder are halogen-containing. The following six pesticides comprise 60.4 percent of those produced in quantities exceeding 1000 metric tons per year: methyl parathion, parathion, malathion (phosphorus-containing), and atrazine, carbaryl, and captan (nitrogen-containing). Each of these pesticides has been demonstrated to be amenable to alkaline hydrolysis.

Wastewater Treatment

Nye and Whittaker (17) showed that treatment of pesticide washwaters by alum coagulation and activated carbon sorption will remove greater than 95 percent of pesticides. The application studied and focused principally on cleaning of pesticide spray applicator airplanes. Alum coagulation was used to reduce the high suspended solids concentrations encountered, e.g. 12,000 to 15,000 mg/l. Objective of the research of Nye and Whittaker (17) was to develop methods for decontaminating pesticide spray planes which were appropriate for small operators. Furthermore, they believed that the information developed could have direct relevance to drum reconditioners.

One major drawback to washwater treatment as envisioned above is the need to deal with residues generated in the treatment processes. It was envisioned that alum sludges would be solidified in concrete mixtures, and that spent activated carbon would be regenerated commercially.

Management Practices

Safety Considerations--

During review of a draft of this report, several reconditioners were emphatic in their comments related to personnel safety. They said that reconditioning of pesticide drums can be extremely dangerous, and only experienced and qualified reconditioners should be used to treat pesticide containers. They stated that such containers should be processed separately using rigorous safety precautions. Furthermore, several maintained that incineration should be used exclusively for pesticide container cleaning.

Supervision--

A NABADA expert in the processing of pesticide containers believes that close supervision is the key to effective drum processing. In fact, some believe that such is the case for all drums. Wearing of respiratory masks, and use of proper protective apparel and equipment in good repair are essential elements in assuring worker protection and a quality product. Workers are instructed to wash thoroughly before breaks and lunch, and to communicate any illness to their foreman even after normal working hours.

Transportation--

California codes (15) require that specified trucks be used for emptied pesticide drums. Specifically the "truck body shall have a steel bed and covered top to protect drums from the sun and open (ribbed) sides for ventilation."

Subsequent to each use, the truck must be washed with a 10 percent NaOH and 2.5 percent sodium gluconate solution. The chemical washes are followed by a water rinse. Washing must take place in the pesticide drum storage area, and disposal of the washing solutions must be in accordance with state requirements (to be discussed later). Additionally, all pesticide drums must have bungs in place during loading and in transit.

Storage--

Pesticide drums are required in California (15) to be stored in a designated area having a climb-proof fence, locked gates, and posted with warning signs. The area shall be protected from flooding, and shall be graded so that vehicle decontamination water, drainage, and other wastes from the storage area can be collected at a central sump. All bungs shall be in place in the area, and emergency cleaning and washing shall be available in the event of skin contact.

Processing and Reuse--

Pesticide drums should be processed separately from other containers, and all flushing and stripping solutions should be used exclusively for such drums. Reconditioned pesticide containers should not be mixed with other containers and should not be sold for or be reused as food, feed, beverage, drug, or cosmetic containers.

Residue Disposal--

In California (15), "all caustic wash solutions and container product residuals shall be disposed of by off-site disposal in a landfill authorized to accept hazardous and/or extremely hazardous wastes in accord with the regulations of the State Department of Health in Title 22, Division 4, California Administrative Code."

Employee Exposure--

California is very specific about measures intended to minimize employee exposures to pesticide residuals (15). Some of the requirements are:

1) All employees must have a baseline cholinesterase determination made by a physician.

2) All employees are required to use protective clothing and equipment.

3) All employees handling pesticide containers must be at least 18 years old.

4) All employees must receive adequate training and instruction in safety procedures for pesticide container handling.

5) No employee is permitted to work alone during the hours 6:00 p.m. to 6:00 a.m., and where supervision exceeds two hour intervals.

6) All protective clothing and equipment shall remain at plant premises, and clean outer clothing shall be worn daily.

7) When illness is apparent or is expected due to exposure, employees must be taken for medical treatment immediately.

SECTION 5

POLLUTANT LOADINGS

SOURCES AND PATHWAYS

Potential pollutant sources and pathways are many and varied depending upon the size and type of drum reconditioning plant. Table 18 summarizes the points of possible pollutant emission. For purposes of this report, drum residues will not be discussed in any detail. Experience has shown that after cleaning, drum surfaces are free from most contamination (17). Additionally, the disposition of discarded drums has been touched upon earlier.

Earley, et al. (7) concluded that if drum furnaces and afterburners are operated properly, air emissions from reconditioning operations pose little problem. Problems related to painting and baking booth exhausts were lessened somewhat by recent shifts toward use of water-based latex paints. However, most paints encountered are not the latex type. Ambient in-plant air does not apparently constitute a problem. This preliminary conclusion will be affirmed or denied as results of this project field sampling become available. Samples were taken from roof exhausts at a large washing and burning plant.

Most attention was devoted to liquid and solid waste streams. Reconditioners almost unanimously claimed that cost-effective and environmentally sound management of solid residues constitutes the most vexing problem faced.

POLLUTANT PARAMETERS

In the NABADA questionnaire, responders cited more than 130 requirements, permits, ordinances, rules, etc. with which they must comply. Table 19 refers to some environmental regulations and requirements applicable to drum reconditioning facilities. These were specifically cited in the NABADA questionnaire responses.

Parameters of concern for burning operations are particulates and uncombusted organics. Usually opacity is the mode of particulate measurement. Earley, et al. (7) have pointed out that drum washing has very low emission rates for noncriteria air pollutants; however, some drum burning facilities can produce criteria pollutants such as hydrocarbons and nitrogen oxides.

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TABLE 18

POTENTIAL POLLUTANT SOURCES/PATHWAYS

STREAM TYPE	LOCATION
● Gaseous	- Drum furnace and afterburner exhaust
	- Painting and baking booth exhausts
	- Ambient in-plant air
● Liquid	- Quench water from post-furnace drum cooling
	- Hot caustic washing and stripping solution
	- Rinse water after caustic washing
	- Sewer discharge
	- Surface water runoff
	- Leak test tank water
● Solid	- Drum drainage at receiving area
	- Ash from drum furnace
	- Sludge from quench water pits
	- Sludge generated by treatment of caustic wash and rinse water process effluents
	- Shot blaster collector dust
● Drum Residue	- Residue in drums after caustic treatment
	- Residue in drums after furnace treatment and before abrasive blasting
	- Residue in drums after abrasive blasting
	- Discarded drums

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TABLE 19

ENVIRONMENTAL REGULATIONS AND REQUIREMENTS FOR RECONDITIONING FACILITIES

FEDERAL

- EPA National Pollutant Discharge Elimination System (NPDES) applications, permits, and quarterly monitoring reports (for direct dischargers)
- EPA pretreatment requirements (for dischargers to publicly owned treatment works)
- EPA Clean Air Act requirements
- EPA Resource Conservation and Recovery Act requirements
- Code of Federal Regulations, Title 40, Environment
- Code of Federal Regulations, Title 49, Transportation

STATE

- State water quality requirements
- State air pollution control requirements
- State solid waste management requirements
- State hazardous waste management requirements
- State wastewater pretreatment requirements
- State wastewater treatment plant permits
- State monitoring and sampling requirements

REGIONAL AND COUNTY

- Air pollution control permits
- Painting booth permits
- Sanitary district or authority permits
- Waste oil hauling permits
- Wastewater treatment plant permits

(continued)

TABLE 19 (con't)

LOCAL

- City air quality rules
- Municipal wastewater treatment plant permits
- Sewer discharge permits
- Boiler operation permits
- Scrap yard permits
- Dust collector permits

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But, even these have minor impact contributing less than 0.0001 percent of the hydrocarbon and negligible amounts of the NO_x national emission burdens. This accounts for the major focus on particulates for air emissions at reconditioning plants.

At one installation, air pollution control requirements pertained to the furnace afterburner, and to paint spray booth and baking oven. Particulate permissible emission rate was 0.14 kg (0.3 pounds) of particulate per 454 kg (1000 pounds) of undiluted exhaust gas. Moreover, stack testing was required. The permissible emission rate for petroleum solvents in the paint spray booth exhaust was 1.8 kg (4 pounds) per hour; however, "...spray, dip or roller coating operations are exempt where the emission rate is equivalent to a maximum of 3.8 liters (one gallon) of solvent used in any hour and the total annual emission of solvent does not exceed 284 liters (75 gallons)." For the baking oven, the petroleum solvent permissible emission rate was 0.5 kg (1 pound) per hour.

Most states and communities simply are concerned with particulate emissions ("smoke"), and focus enforcement on that parameter. A few do extend concern to SO_2, CO, NO_x, photochemical oxidants, and hydrocarbons. In Japan, the Osaka Prefecture has issued specific limitations for certain gaseous emissions. These are shown in Table 20.

Because of the nature and complexity of the operation, washing plants are regulated for many more parameters. All washing operations which discharge directly to receiving water bodies must file NPDES permits. Only about 10 percent of washing facilities are direct dischargers; most recycle and reuse caustic and rinse water or discharge to public sewers. In the NABADA questionnaire, water quality limitations for dischargers to publicly owned sewerage systems were investigated. Responders were asked to indicate the parameters which are included in sewer regulations. Those mentioned must often are: BOD, suspended solids, pH, oil and grease, cadmium, lead, and zinc. Table 21 shows these limitations along with the mean value and low and high ranges for 46 parameters. For comparison, limitations for three foreign systems are shown in Table 22.

Regulations for solids and hazardous wastes are not expressed in terms of concentrations or emission rates. Rather, regulations are oriented toward hauling and disposal practices and the type of facility which can safeguard the environment commensurate with the degree of hazard involved. Manifests may be required to permit acceptance of certain empty hazardous material drums.

GENERATION AND DISPOSTION MODES

Where potential air pollutants come from, and where they go

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TABLE 20

STANDARDS FOR GASEOUS EMISSIONS IN OSAKA PREFECTURE

GAS	MAXIMUM PERMISSIBLE EMISSION (in parts/million)
Acetaldehyde	2
Acrolein	0.01
Ammonia	1
Benzene	0.5
Formaldehyde	0.1
Gasoline	5
Hydrogen Chloride	0.1
Hydrogen Sulfide	0.1
Methanol	5
Methyl Ethyl Ketone	4
Phosgene	0.005
Toluene	2
Xylene	2

EPA-287 (Cin.)
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TABLE 21

WATER QUALITY LIMITATIONS FOR DISCHARGES TO PUBLICLY OWNED SEWERAGE SYSTEMS

Parameter	No. of Reported Limitations	Mean Value*	Range* Low	Range* High
BOD (biochemical oxygen demand)	12	229	20	no limit
COD (chemical oxygen demand)	5	345	25	450
Suspended Solids	12	266	25	no limit
Total Dissolved Solids	4	625	500	1000
pH (range)	13	5.3 to 9.8	4.5	10.5
Oil and Grease	11	162	0	1000
Fats and Oils	2	100	100	100
Fuel Oil	1	0	-	-
Benzene	1	0	-	-
Cyanides	8	2.1	0.1	10
Formaldehyde	1	5.0	-	-
Gasoline	1	0	-	-
Naphtha	1	0	-	-
Pesticides	4	0	-	-
Phenol	5	0.5	0.3	0.5
Volatile Organics	1	5.0	-	-
Chlorides	1	250	-	-
Fluorides	1	0	-	-
Phosphates	2	21	12	30
Total Kjeldahl Nitrogen	1	no limit	-	-
Temperature	6	140°F	110°F	150°F
Antimony	5	1.0	0	5.0
Arsenic	7	0.2	0.05	0.5

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TABLE 21 (con't)

Parameter	No. of Reported Limitations	Mean Value*	Range* Low	Range* High
Barium	7	2.9	1.0	5.0
Beryllium	4	0.3	0	1.0
Bismuth	4	0.3	0	1.0
Boron	4	0.6	0.5	1.0
Cadmium	10	1.1	0.002	3.0
Chromium (total)	9	6.5	0.05	25
Chromium (hexavalent)	6	0.7	0.05	1.0
Cobalt	4	0.05	0	0.2
Copper	9	1.0	0.2	3
Iron	6	4.0	1.0	5.0
Lead	11	0.9	0.1	5
Manganese	7	2.0	0.05	5.0
Mercury	5	0.007	0	0.02
Molybdenum	4	0.03	0	0.1
Nickel	9	2.4	0.5	10
Rhenium	4	0.1	0	0.5
Selenium	7	0.6	0.02	2.0
Silver	7	1.1	0.05	5.0
Strontium	4	0.1	0	0.5
Tellurium	4	0.1	0	0.5
Tin	4	0.8	0	1.0
Uranium	1	0	-	-
Zinc	11	5.4	1.0	15

* Values reported in milligrams/liter unless specified otherwise.

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TABLE 22

WATER QUALITY LIMITATIONS FOR DISCHARGES TO SELECTED FOREIGN SEWERAGE SYSTEMS

PARAMETER	VALUE (mg/l)		
	WEST GERMANY	JAPAN	ENGLAND
BOD	-	60	-
COD	-	60	-
Suspended Solids	-	90	400
pH	6.0-9.0	-	6-10
Cyanides	1.0	-	10.0
Phenol	2.0	-	-
Oil	0	-	200
Grease and Fats	0	-	100
Hexane Extractables	-	5	-
Temperature	-	-	110°F
Metals	2.0	-	30
Iron	20.0	-	-
Sulfate	300	-	-
Magnesium	300	-	-

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after generation is fairly straight-forward. Clearly, the major potential source is burned drums, and the disposition is assumed to be through complete combustion in the afterburner. The situation for liquid waste streams is not nearly as clear. Major liquid waste streams are: hot caustic washing solutions, rinse waters, and surface runoff. How potential pollutants enter each of these streams is evident (although less so for surface runoff). On the other hand, there are several options for dealing with each of these streams. Some of these methods and the percentage of reconditioners who employ them are shown in Table 23. The percentage of reconditioners recycling and reusing caustic washing solutions continues to increase. Similarly, the percentage of reuse of rinse water will increase, but probably not as fast.

The NABADA survey showed that nearly half of all reconditioners (including plants that only burn) send some wastewater to publicly owned sewerage systems. Mean daily flow is about 56,781 liters/day (15,000 gallons/day). Nearly 20 percent claim to be completely closed cycle systems in terms of water use.

Only about 31 percent of reconditioning plants collect surface runoff. Table 23 shows what happens to the collected runoff. The claim in the NABADA survey that almost 36 percent of plants collecting runoff treat it before discharge is difficult to believe. During the course of this study the project team saw no instances of such practice.

During 1973, nearly 90 percent of the residues encountered in drum reconditioning ultimately were disposed in landfills (some were burned prior to landfilling the ash) (4). Table 24 shows the disposal methods by region and nationally using Checchi Report data (4). Table 25 is for the recent NABADA survey made in conjunction with this report. Data in Table 25 show comparable results with the 1973 figures for sludges and ash, assuming that contractor hauling and landfilling are synonymous. The trend for sludge disposal is expected to increase toward more incineration, just as it has for concentrated liquid drainage. The reason is that recent RCRA requirements make land disposal more difficult and expensive.

DISCHARGE DATA

Air Emissions

During 1976, an incinerator stack test was made at a now-defunct drum burning operation. The test was conducted to determine if incinerator particulate emissions were in compliance with state air pollution control laws. The incinerator tested had an afterburner maintained at 732°C (1350°F). Tests were conducted using process feed rates of from 120 to 140 drums/hr. Standard EPA test methods were employed.

TABLE 23

METHODS FOR DEALING WITH LIQUID WASTE STREAMS

METHOD	PERCENTAGE OF RECONDITIONERS USING THE METHOD		
	Caustic Solution	Rinse Water	Runoff
Discharge to public sewer	7.8	42.5	42.9
Neutralize and discharge to public sewer	13.7	-	-
Discharge to stream	0	2.5	21.4
Recycle and reuse	52.9	35.0	-
Treat at own treatment plant and discharge to stream	2.0	10.0	35.7
Discharge some and recycle some	21.6	-	-
Haul to landfill	2.0	7.5	-
Evaporate	-	2.5	-
TOTAL	100.0	100.0	100.0

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TABLE 24

RESIDUE DISPOSAL METHODS BY REGION IN 1973 (4)

METHOD	PERCENTAGE OF RECONDITIONERS USING THE METHOD Eastern Region	 Central Region	 Western Region	 Total U.S.
Landfill	58.3	72.5	80.0	67.3
Burn and landfill				
- on-site	8.3	-	-	3.4
- off-site	16.7	13.8	20.0	15.6
- no residue	8.3	6.9	-	6.9
Discharge to sewer	4.2	-	-	1.7
Store	4.2	-	-	1.7
Contract burning	-	3.4	-	1.7
Contractor hauling	-	3.4	-	1.7
TOTAL	100.0	100.0	100.0	100.0

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TABLE 25

METHODS FOR DEALING WITH RESIDUES (NABADA SURVEY)

METHOD	PERCENTAGE OF RECONDITIONERS USING THE METHOD		
	Concentrated Liquid Drainage	Sludges and Solid Drainage	Burned Ash
Discharge to sewer	6.0	1.9	-
Contractor hauling	40.0	38.5	32.3
On-site land disposal	4.0	7.7	-
On-site burning	16.0	-	-
Landfill off-site	24.0	36.5	38.7
Return to emptier	2.0	1.9	3.2
Burn and landfill	-	5.8	-
Dispose with other sludges	-	-	25.8
Store	-	1.9	-
Own treatment plant	6.0	-	-
Drain to caustic solution	2.0	-	-
Off-site burning	-	5.8	-
TOTAL	100.0	100.0	100.0

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Results of the testing (in English units) showed an average particulate concentration of 0.0149 grains per dry standard cubic foot. Corrected to 12 percent carbon dioxide, the average particulate concentration was 0.102 grains per dry standard cubic foot. By comparison, state regulations required a maximum of 0.2 grains per dry standard cubic foot (corrected to 12 percent CO_2). An average of three runs of the incinerator stack test is shown in Table 26. The incinerator was well below the state standard for particulate emissions even though most afterburners are operated at slightly higher temperatures, i.e. greater than 760°C (1400°F). (The NABADA average afterburner temperature is 810°C or 1490°F).

In conjunction with the EPA source assessment of the drum cleaning industry (7), tests were conducted at a large drum incinerator plant. Results showed that particulate and organic emissions were well below all relevant criteria and standards, provided that the furnace afterburner was maintained and operated properly.

Wastewater Discharges

Because of their similarity, rail tank car, tank truck, and drum cleaning were dealt with together in an EPA source assessment (7). There are many similarities especially in the use of caustic washing solutions. Hence, it is not surprising that wastewater characteristics bear some resemblance. Table 27 compares wastewater characteristics for petroleum barge cleaning, vehicle washracks, and several tank truck cleaning terminals (7) (18)(19)(20)(21). In general, wastewaters from these cleaning operations have high values for pH, COD, oil and grease, and solids content. Additionally, these wastewaters are further characterized by wide variability from sample to sample. For example, an EPA study has shown that the variability ratio can be as high as 19 for suspended solids concentrations in tank truck raw wastewater (21). The variability ratio is defined as values at 90 percent level of occurrence divided by those at the 10 percent level. Thus, while it is useful to have an idea of average concentrations found in certain wastewaters, it often is more important to be aware of the range of values likely to be encountered.

Kinman, *et al*. (22) demonstrated that drum reconditioning wastewater also is characterized by high pH, COD, and solids content, as well as wide variability. Table 28 shows two characterizations made by Kinman, *et al*. (22). Data set number 1 is of interest because of the large number of observations, and the statistical analysis made.

Data obtained in the recent NABADA survey are collated in Table 29. As with other cleaning operations (Table 27), and previous drum reconditioning wastewater characterizations (Table 28), high pH, COD, and solids values are evident. Likewise, there is

TABLE 26

AVERAGE TEST RESULTS FOR A DRUM INCINERATOR STACK TEST

Parameter	Result
Stack Temperature	519.9°F
Moisture	4.88%
Stack Gas Velocity	56.48 fps
Stack Flow Rate (actual)	22,071 CFM
Stack Flow Rate (dry)	11,304 SCFM
Particulate Mass Rate	1.44 lbs/hr
% Isokinetic	100.6%
Particulate Concentration	
- uncorrected	0.0149 gr/dscf
- corrected to 12% CO_2	0.102 gr/dscf

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TABLE 27

CLEANING OPERATIONS WASTEWATER CHARACTERISTICS*

PARAMETER	Petroleum Barge Cleaning (18) (Range)**	Vehicle Washrack (19) (Range)	Tank Truck Washing Terminal (20) (Mean)	Tank Truck Washing Terminal (21) (Mean)	Tank Truck Washing Terminal (7) (Range)
pH	5.0-11.1	6.5-11.9	11.0	-	10.5-12.5
COD	400-91,200	64-3,400	24,553	12,000	1,800-11,000
Oil and Grease	1.1-638	19-8,700	43,415	-	110-350
Conductivity (µmhos/cm)	1,200-31,500	-	-	-	-
Total Solids	1,262-31,143	570-12,900	6,901	-	-
Total Fixed Solids	918-25,473	-	-	-	-
Total Volatile Solids	308-7,033	-	6,406	-	-
Volatile Solids, %	11-28	-	-	-	-
Total Suspended Solids	73-2,696	-	4,907	4,035	300-1,300
Total Fixed Suspended Solids	0-1,672	-	-	-	-
Total Volatile Susp. Solids	21-1,024	-	-	-	-
Volatile Suspended Solids,%	16-100	-	-	-	-
TDS	1,132-30,793	-	1,993	-	-
TOC	-	24-1,700	-	-	-
Phosphates	-	2-580	3.4	-	-
LAS	-	0-530	-	-	-
Organic-N	-	-	19.3	-	-
Alkalinity	-	-	680	-	-
Phenol	-	-	0.1	12	1-250
BOD	-	-	-	2,800	600-2,000

* All values in milligrams/liter unless specified otherwise.
** After gravity separation.

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TABLE 28

DRUM RECONDITIONING WASTEWATER CHARACTERISTICS (22)
(concentrations in milligrams/liter)

Parameter	Sample Set No. 1					Sample No. 2
	No. of Observations	Mean	Standard Deviation	Maximum Value	Minimum Value	
pH	34	-	-	12.92	8.40	12.72
COD	34	3262	1156	5700	1552	15,200
Total Residue	32	2802	934	5234	1427	15,110
Total Volatile Residue	32	1259	448	2608	625	6,680
Total Fixed Matter	32	1543	609	3214	372	8,430
Total Suspended Matter	32	1075	495	2805	260	3,080
Volatile Suspended Matter	32	771	351	1660	160	2,640
Fixed Suspended Matter	32	305	247	1145	13	440
Dissolved Matter	32	1727	913	4260	383	12,030
Settleable Matter	29	605	73	2988	0.8	2

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TABLE 29

WASTEWATER DISCHARGE ANALYSES*

PARAMETER	No. of Observations	Mean	Standard Deviation	Range Low	Range High
Aluminum	2	181.5	195.9	43	320
Antimony	6	0.3	0.4	0	1
Arsenic	3	0.13	0.23	<0.03	0.40
Barium	3	9.3	9.0	<1.0	10
Beryllium	3	0	0	0	0
Bismuth	2	0	0	0	0
BOD_5	31	4,599	9,882	10	44,133
Boron	4	2.5	4.3	<0.05	8.9
Bromide	1	0	-	-	-
Cadmium	12	0.10	0.26	0.0002	0.90
Calcium	4	74	60	28	162
TOC	5	5,397	8,455	71	20,412
COD	24	24,549	64,889	91.5	310,909
Chloride	6	2,169	1,540	6.7	4,144
Chromium (total)	26	12.5	43.3	0.023	224
Chromium (hexavalent)	4	0.11	0.12	0	0.22
Cobalt	2	0.2	0.2	0	0.3
Color (Pt/Co units)	3	420	312	60	600
Copper	16	2.4	5.7	0	23.0
Cyanide (total)	7	1.4	2.0	0.2	5.9
Cyanide ("A")	5	0.5	0.4	0.2	1.2
Fluoride	1	1.2	-	-	-
Iron	12	114	294	1.6	1,041
Lead	29	45.8	154.5	0	682
Magnesium	4	23	21	5.5	54
Manganese	4	1.5	2.4	0	5
Mercury	11	1.0	1.9	0	5.9
Molybdenum	3	0	0	0	0
Nickel	12	0.3	0.4	0	1.0
Nitrogen (Total Kjeldahl)	4	18.6	15.3	6.2	40

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TABLE 29 (con't)

PARAMETER	No. of Observations	Mean	Standard Deviation	Range Low	Range High
Nitrogen (Ammonia)	4	13.3	10.8	1.96	23
Nitrogen (Nitrate)	5	4.6	5.1	0.66	13.2
Oil and Grease	37	10,228	42,656	19.2	248,340
pH	39	10.9	3.3	1.8	13.6
Phenols	21	43.8	45.5	0.044	148
Phosphorus (total)	8	34.3	25.1	5.04	68.48
Potassium	2	33	15	22.0	43
Selenium	4	0.12	0.23	0	0.47
Silicon	3	75	33	37	94
Silver	4	0.01	0.02	0	0.04
Sodium	4	10,157	9,643	1,678	19,000
Strontium	2	0	0	0	-
Sulfate	4	7,747	8,384	16	15,000
Sulfide	3	14.6	22.1	0.7	40.0
Sulfite	1	<1	-	-	-
Surfactants (MBAS)	2	2.0	1.6	0.8	3.1
TDS	4	8,514	9,264	944	22,000
Total Solids	7	8,701	12,013	970	35,000
Total Fixed Solids	1	5,414	-	-	-
Total Suspended Solids	46	2,435	4,113	77	24,000
Total Volatile Solids	2	265	92	200	330
Mineral Suspended Solids	1	32	-	-	-
Volatile Suspended Solids	1	108	-	-	-
Thallium	1	<0.1	-	-	-
Tin	6	1.1	2.4	0	6
Titanium	2	115	163	0	230
Turbidity (NTU)	3	33	10	21	39
Zinc	33	24.0	46.5	0.1	228

* All values in milligrams/liter unless specified otherwise.

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wide variability in data, as shown graphically by the low and high values of the parameter data sets. Similarly, in the statistical analysis, standard deviations in excess of 100 percent of the mean are not uncommon.

There is no reason to expect that data having so few points and the nature of the cleaning process should lend itself to neat statistical analysis. However, mean values often are skewed by single data points. Hence, the data set for each of the 58 parameters in Table 29 was examined to determine which values were outside of the 99 percent confidence level. Eleven of the 58 showed that some values were outside of this confidence limit. Such values were discarded and a new analysis made. The process was repeated until all data sets conformed to the 99 percent confidence limit. The statistically adjusted discharge values are given in Table 30. This is not to imply that these values are better or worse than those in Table 29. It merely means that outlying values have been discarded in an attempt to present values which potentially could be more typical.

In conjunction with securing wastewater data in the NABADA survey, some information was obtained on quench water and treated wastewater samples. Table 31 reports on this data. Less confidence should be placed in it, because it usually represents few data points.

Very few drum reconditioning plants routinely wash pesticide drums. Such drums may pass through occasionally at typical plants, but they are well dispersed within the total processing inventory. A few drum reconditioners do wash pesticide drums on a regular basis. Table 32 reports analysis of microcontaminants in such a washing plant's caustic solutions. These values were compared against proposed EPA limitations based upon human health effects as reported by Convery, et al. (23). A comparison was able to be made for 11 compounds. Three were below the proposed water quality criteria: alpha BHC, HCB, and diethyl hexyl phthalate. Table 33 shows the amount by which the remaining eight compounds exceeded the proposed criteria.

Readers should be careful in drawing conclusions on the comparison in Table 33. The criteria are for direct discharge of wastewaters, whereas the samples containing microcontaminants were wash solutions bound for further processing. If such processing includes phase separation with incineration of the floating and settleable fractions, then the microcontaminants probably will be destroyed. If the microcontaminants are recycled along with reused caustic solution, then buildup in the caustic stripping and washing solution could be a problem. If the microcontaminants follow the sludge and subsequently are landfilled, then problems could arise in terms of RCRA compliance.

TABLE 30

STATISTICALLY ADJUSTED DISCHARGE VALUES*

Parameter	No. of Observations	Mean	Standard Deviation	Range Low	Range High
BOD_5	27	1,262	899	10	3,617
Cadmium	11	0.03	0.06	0	0.15
COD	19	4,011	2,835	91.5	8,638
Chromium (total)	25	4.0	4.0	0.023	11.0
Copper	14	0.7	0.8	0	2.5
Iron	11	29.3	34.0	1.6	54
Lead	24	2.1	2.2	0	6.7
Oil and Grease	33	901	1,202	19.2	3,970
pH	37	11.4	2.7	4.8	13.6
Total Suspended Solids	44	1,669	1,662	77	5,195
Zinc	30	10.5	8.6	0.1	34

* All values in milligrams/liter unless specified otherwise

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TABLE 31

ANALYSES OF QUENCH WATER AND TREATED WASTEWATER

Parameter	Average Values* Quench Water	 Treated Wastewater
Antimony	<0.10	<0.01
Arsenic	0.007	0.01
Barium	-	0.8
Beryllium	-	<0.01
Bismuth	-	<0.05
BOD_5	750	250
Boron	<1.0	0.7
Cadmium	0.062	0.04
TOC	1,412	-
COD	4,810	650
Chlorides	9	2,915
Chromium (total)	0.071	4.7
Cobalt	-	<0.01
Color (Pt/Co units)	>150	200
Copper	0.153	<0.1
Iron	4.105	-
Lead	0.575	6.2
Manganese	-	1.11
Mercury	<1	<1
Molybdenum	-	<0.1
Nickel	0.080	0.077
Nitrogen (Total Kjeldahl)	17.80	-
Nitrogen (Ammonia)	3.99	-
Nitrogen (Nitrate)	4.68	-
Oil and Grease	652	229
pH	7.7	6.4
Phenols	30.64	-
Phosphorus (Ortho)	0.03	-
Selenium	0.012	<0.005
Silver	<0.010	0.13
Sulfate	68	17
Sulfide	<0.1	-
Sulfite	1	-
Surfactants (MBAS)	2.33	-
TDS	424	4,970
Total solids	2,056	5,056

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TABLE 31 (con't)

Parameter	Average Values* Quench Water	 Treated Wastewater
Total Suspended Solids	466	85
Total Volatile Solids	1,632	-
Mineral Suspended Solids	50	-
Volatile Suspended Solids	416	-
Tin	<0.80	<0.1
Turbidity	750	-
Zinc (NTU)	1.112	25.2

* All values in milligrams/liter unless specified otherwise.

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TABLE 32

MICROCONTAMINANT CONCENTRATIONS IN WASHING PLANT SOLUTIONS

(concentrations in micrograms/liter)

PARAMETER	No. of Observations	Average	Maximum
Alpha BHC	1	0.002	-
HCB	1	0.019	-
Heptachlor	2	0.102	0.144
Gamma Chlordane	3	0.414	1.07
Ortho Para DDE	3	1.961	5.31
Alpha Chlordane	2	0.400	0.77
Para Para DDE	3	3.139	8.42
Ortho Para DDD	2	4.225	8.42
Endrin	3	11.972	34.08
Para Para DDD	2	0.252	0.26
Ortho Para DDT	1	0.049	-
Para Para DDT	1	0.424	-
Parathion	2	5.496	10.53
Dioxanon	1	0.221	-
Toxaphene	2	61.74	108.18
Methoxychlor	1	2.74	-
Diethyl Hexyl Phthalate	1	4.60	-
C10-Hydrocarbons	2	48.42	94.01
Heptachlor Epoxide	1	0.06	-
C11-Hydrocarbons	2	27.59	53.45
C12-Hydrocarbons	1	20.69	-
C13-Hydrocarbons	2	63.41	123.97
C14-Hydrocarbons	2	50.27	97.44
Acenapthene	2	32.25	63.03
C15-Hydrocarbons	2	90.63	175.00
Fluorene	1	17.68	-
Atrazine	1	12.59	-
Phenanthrene	2	14.53	28.57
Anthracene	2	11.30	21.51
Dieldrin	2	0.100	0.19

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TABLE 33

COMPARISON OF MICROCONTAMINANTS WITH PROPOSED WATER QUALITY CRITERIA

Compound	Observed Value ÷ Proposed Criterion
Heptachlor	443
Gamma Chlordane	345
Alpha Chlordane	333
Endrin	12
Para Para DDT	433
Dieldrin	2.3×10^6
Toxaphene	1.3×10^5
Acenapthene	1613

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Residues

Drum drainage, both liquid and solid, is a major source of residue in the drum cleaning process. Theoretically, drums received by reconditioners are empty; however, in actuality the drums contain residuals adhering to the surfaces, in some cases in significant amounts. Furthermore, drum emptiers, in an attempt to avoid high sludge disposal costs, sometimes purposely leave materials in the drums hoping that reconditioners will deal with these wastes. Stringent RCRA provisions and difficult sludge management problems have led reconditioners to define what is meant by "empty" drum. In this regard, during September 1980, NABADA issued a document entitled, "Federal Regulations and NABADA Guidelines on 'Empty' Drums". This document is quoted below in its entirety.

"In conjunction with the issuance of federal hazardous waste regulations by the Environmental Protection Agency (EPA) and the Department of Transportation (DOT), on May 19 and May 22, 1980, respectively, the National Barrel & Drum Association has prepared this guideline to clarify what is meant by 'empty' when describing a drum containing residue of its former contents. NABADA recommends adoption of this guideline by all emptiers, dealers and reconditioners of used steel drums, and regulatory bodies:

"I. Drums that have not been 'cleaned and purged' of all DOT-regulated residues must be transported as if full, with all DOT markings, labeling, and closures in place. DOT 49 CFR 173.29(a)(1), Federal Register May 22, 1980.

"II. Empty drums that formerly contained any product listed in Section 261.33(e) of EPA's RCRA regulations must be triple-rinsed with an effective solvent. If not triple rinsed, then such a drum is a hazardous waste. EPA 40 CFR 261.6, 261.33(c)(1), Federal Register May 19, 1980.

"III. Drums must be emptied effectively, and residue remaining in the drum shall not exceed 1" in depth. NABADA Guideline, August 1980."

On November 19, 1980, the EPA Administrator approved regulations almost identical to the NABADA definition of empty containers, and the drum handling guidelines outlined above.

How does the one inch guideline compare with volumes actually found in received drums? (Because the regulation specifies an English unit as its primary measure, metric conversion is not made.) Six estimates have been made previously, and are shown in Table 34. If the NABADA and EPA guideline of one inch is used, then the liquid volume would be 1.6 gallons (1/35 x 55 gallons). Assuming the liquid is water, the weight would be 13.1 pounds (1.6 gal x 8.34 pounds/gallon). This weight should be multiplied

TABLE 34

ESTIMATES OF RESIDUE FROM DRUM DRAINAGE

SOURCE OF ESTIMATE	ESTIMATE OF DRUM DRAINAGE	
	Liquid in gallons	Solid in pounds
Calculated from NABADA August 1980 Guideline	1.6	13.1
Temple, Barker and Sloane, Inc. (24)	0.6	5.0
Langella, 19th NABADA Technical Forum, Nov. 1978	1.0	5.0
Checchi Survey (4)	0.12 0.25	0.75 -
Hershson, NABADA Communication to A.D. Little, Inc., Dec.1979	- -	open head 2.0 tight head 4.0
NABADA Questionnaire, March 1980	0.25 0.65	0.75 5.4
Range	0.12 - 1.6	0.75 - 13.1
Average	0.41	4.5
BEST ESTIMATE (TSA)	0.65	5.4

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by the specific gravity of the material to determine actual weight. In a recent EPA report (24), Temple, Barker and Sloane, Inc. used 5 pounds as the amount of material remaining in used drums (0.6 gallon as a liquid). Mr. Frank Langella, former Chairman of NABADA Technical Forums, estimated liquid and solid drum residue as received at 1 gallon and 5 pounds, respectively. The estimate is based upon his experience in the reconditioning field.

In 1973, the Checchi Report for NABADA (4) resulted in data which calculates to volumes of 0.12 gallon and 0.75 pound. A Checchi representative claimed the liquid volume was 0.25 gallon in the 1973 NABADA Technical Forum. These figures match closely with volumes calculated from responses to question number 46 in the recent NABADA questionnaire, i.e. 0.25 gallon and 0.75 pound. Unfortunately, both sets of data likely are wrong. A companion question (number 45) in the recent NABADA questionnaire recognized the tendency to understate drum residue in the Checchi Report and its similar counterpart in the NABADA questionnaire. As a result, the question was phrased in a different way. The result, on the basis of 39 responses, was 0.65 gallon and 5.4 pounds. This matches closely with the Langella and Temple, Barker and Sloane estimates.

The final estimate was made by Mr. Morris Hershson, NABADA President, in response to a survey being made by Arthur D. Little, Inc. for EPA. Little was attempting to determine the volume of hazardous waste generated by the drum reconditioning industry in the United States. Information given to Little by Mr. Hershson indicated that drum residues are 4 and 2 pound for tight head and open head drums, respectively. Moreover, reconditioners annually reprocess 30 million and 20 million tight and open head drums, respectively. About 60 percent of these residues were estimated by Mr. Hershson to be hazardous. Using the figures above about 44,000 metric tons per year of hazardous waste would result from drum handling. Little came up with a volume of 73,000 metric tons per year. If NABADA questionnaire data is used in conjunction with Mr. Hershson's estimate of 60 percent hazardous, the annual volume would be 61,000 metric tons.

Mr. Hershson's estimates of drum residue were not comparable to the others. For example, the 2 pound residual for open heads is after burning. Hence, heavier reliance was placed upon the Langella, Temple, Barker and Sloane, and NABADA (question 45) estimates. Touhill, Shuckrow and Associates, Inc. believes that the NABADA estimate matches well with the others and can be documented easily. Therefore, TSA believes that 0.65 gallon and 5.4 pounds represent the best estimate and should be used.

Some reconditioners have used a disincentive cost to reduce the probability of receiving a drum with excessive residual. They have a surcharge for receipt of a "full" drum. In some cases, full is defined as any amount in excess of emptiness guidelines.

Just as caustic washing solutions have high pH, COD, oil and grease, and solids concentrations, so do caustic sludges, only in much higher amounts. Table 35 gives a summary of data obtained in conjunction with the NABADA questionnaire. One source claimed that an analysis of a sluge sample contained no halogenated or sulfonated compounds and that 30 to 40 percent of the organics were aliphatic hydorcarbons. Table 36 reports data submitted by one reconditioner pursuant to obtaining an industrial waste disposal permit.

MONITORING

Most burning plants monitor furnace off-gases using opacity measurements or simple visual inspection for visible emissions. In the case of visual inspection, some use Ringelmann Charts to determine the severity of particulate emissions. Even though stack testing may be required to obtain an air emission permit, such testing is not often required on a routine basis.

Monitoring by regulatory agencies usually focuses on "smoke". Thus, even the regulatory agencies use visual means most often as the primary control mechanism. Strictest rules and regulations, and monitoring requirements are those in Southern California as promulgated and enforced by the South Coast Air Quality Management District.

In the NABADA questionnaire, a question was asked, "Has your wastewater ever been analyzed for priority pollutants?" An affirmative answer was given by nearly 35 percent of the responders, about half of whom attached such analyses. It turned out that the question was misunderstood. The question referred to consent decree Priority Pollutants (for which only one response was submitted), whereas most responders submitted data on all measured pollutants.

Table 37 indicates the percentage of reconditioners who measure or are monitored for certain water quality parameters.

In general there are three levels of water quality monitoring requirements imposed by regulatory agencies: 1) submission of copies of NPDES quarterly monitoring reports, 2) compliance with general monitoring and reporting procedures, and 3) adherence to specific permit monitoring requirements. Use of NPDES reports is a frequently employed method. It simply requires that direct dischargers submit the same quarterly reports to state or local agencies as the EPA's NPDES permits. The procedure streamlines reporting and appears to be beneficial for all concerned. Some agencies spell out general monitoring and reporting conditions in considerable detail. For example, the State of

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TABLE 35

CAUSTIC SLUDGE COMPOSITION*

Parameter	No. of Observations	Average	Range Low	Range High
pH	6	12.3	11.4	13.2
Oil and Grease	5	117,654	3,826	240,000
Floating Oil	1	323.7	-	-
TDS	3	192,533	110,000	314,600
Total Solids	5	368,047	11,837	547,000
Suspended Solids	4	150,822	2,150	394,000
BOD	1	12,000	-	-
COD	1	580,000	-	-
TOC	3	174,333	35,000	420,000
Arsenic	2	1.64	0	3.28
Barium	1	651	-	-
Cadmium	4	9.6	1.9	13.5
Calcium	1	1,687	-	-
Chlorides	2	1,390	880	1,900
Chromium (total)	6	199	0.01	469
Chromium (hexavalent)	2	0.64	0.009	1.28
Copper	4	2,393	22	9,000
Cyanides	4	10	3.0	19
Fluorides	2	17.5	9.0	26
Iron	4	24,922	1,087	76,800
Lead	4	4,554	375	15,100
Manganese	2	290	30	550
Mercury	4	0.48	0.00147	1.51
Nickel	5	29.2	0.83	82
Phenol	4	199	19.05	500

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TABLE 35 (con't)

Parameter	No. of Observations	Average	Range Low	Range High
Phosphates	2	7,500	2,100	12,900
Potassium	1	2,010	-	-
Selenium	2	30.5	8.7	52.3
Silica	2	5,325	3,300	7,350
Silver	4	2.3	0.5	5.6
Sodium	1	8,455	-	-
Sulfates	1	12,300	-	-
Zinc	6	6,791	25.95	39,000
Specific Weight	1	10.08	-	-
Flash Point	1	>210°F	-	-
Ash Content	1	14.36%	-	-

*All values in milligrams/liter unless specified otherwise.

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TABLE 36

SLUDGE TANK ANALYSES
(concentrations in mg/kg)

Parameter	Tank 1	Tank 2	Tank 3
Oil and Organics	31%	52.4%	8.2%
Water	33%	27.0%	19.0%
Ash	36%	20.6%	69.0%
Lead	10	4	11
Zinc	1400	1100	38,000
Nickel	222	433	290
Copper	180	233	2180
Beryllium	-	2	4
Cadmium	48	14	340
Chromium	33	8	22
Mercury	-	2	1
Chlorine	384	288	221
Bromine	31	14	12
Phosphorus	7400	1890	1800
Sulfur	3900	3900	4400
Phenol	90	-	110

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TABLE 37

WATER QUALITY MONITORING

PARAMETER	PERCENTAGE OF RECONDITIONERS WHO MEASURE OR ARE MONITORED
Oil and Grease	53.3
pH	46.7
Suspended Solids	46.7
BOD	40.0
Phenol	33.3
Lead	33.3
COD	26.7
Zinc	26.7
Chromium	26.7
Cadmium	26.7
Nickel	20.0
Copper	20.0
Pesticides	20.0
Cyanides	13.3

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Maryland describes procedures for: representative sampling, reporting monitoring results, reporting schedules, sampling and analysis methods, data recording requirements (e.g. place, date, and time of sampling; date of analysis; name of analyzer; analytical technique used; results), monitoring equipment maintenance, and records retention.

A local district in Virginia specifically required the following from a reconditioner: "One (1) grab sample shall be collected and analyzed monthly for pH, oil and grease, zinc (Zn), lead (Pb), and chromium (Cr) on alternating work days (Monday of the first month, Tuesday of the second month, etc.). Results of these analyses shall be forwarded, in writing, to (this agency) within ten (10) days of sampling date. All analyses shall be performed in accordance with (the appropriate section of the agency's) 'Industrial Wastewater Discharge Regulations'." These requirements are typical of many local agencies.

In cases where monitoring is not required, agencies often will include a provision in the wastewater permit allowing for access to the plant site, its discharge point, or sewer connections.

Monitoring for solid waste disposal is not well developed. However, promulgation of RCRA requirements is expected to accelerate such monitoring as well as testing methods.

SECTION 6

POLLUTION CONTROL PRACTICE

PROCESSES AND EQUIPMENT

Air Emissions

All reconditioning drum furnaces have afterburners to consume particulates and organics not burned in the furnace main chamber. About 37 percent of those who burn drums have air pollution control equipment in addition to the afterburner. Japanese reconditioners generally regard the following as the four possible alternatives for air pollution control: 1) direct combustion in the 649°C to 799°C (1200°F to 1470°F) temperature range with an afterburner residence time of 0.3 to 0.7 seconds; 2) catalytic oxidiation in the 349°C to 499°C (660°F to 930°F) range; 3) sorption using activated carbon, silica gel or other materials; and 4) scrubber systems. U.S. reconditioners concur with these basic alternatives, but extend them also to use for reduction of air pollution from painting operations. Worldwide the direct combustion and afterburner method is the one most frequently used. The other methods usually are adjuncts to this primary method.

The 37 percent of reconditioners in the NABADA survey who used control devices beyond afterburners employed varied equipment and techniques. Some optimized existing equipment, using automatic ducts to regulate air flow, and entry and exit air curtains for better and more efficient combustion. Others used scrubbers, packed towers, baghouses, and dust collectors. Presently, scrubbers are required in California. A manufacturer of air pollution control equipment recommends wet scrubbers to remove SO_2, HCl, and toxic gases from afterburner off-gases. Packed towers are regarded as variants of scrubbers. One reconditioner uses a 0.6 meter (2-foot) diameter upflow tower packed with more than 1.2 meters (4-feet) of polypropylene saddles. Exhaust gases pass through Koch Engineering Company 16.5 cm (6½-inch) "Fleximesh" at a velocity of about 2.4 to 3.7 m/sec (8 to 12 fps).

Baghouses often are used for painting booth exhausts, whereas dust collectors are used for shot blasters (Torit and Wheelabrator Frye are typical manufacturers).

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There is increasing interest in the use of waste heat. Waste heat boilers are used, and a method for using waste heat to dry sludge has been discussed elsewhere.

Aqueous Waste Streams

Large Container Cleaning--

Cleaning of large containers such as petroleum barges, railroad tank cars, and tank trucks bears many similarities to drum cleaning. An EPA assessment (7) of emissions from container cleaning included these categories, and generally assumed that the methods for treating aqueous waste streams from one operation would apply broadly to another. Combinations of the methods described in the report which could be used to treat large container cleaning solutions could also be used by drum reconditioners.

Stryker and Ball (18) have described a rigorous treatment method used to treat aqueous wastes from petroleum barge cleaning. The method is an alternative to the more common practice of gravity separation followed by disposal to evaporation/seepage ponds. Holding tanks, in the more sophisticated treatment system, are used to equalize flow. Some sedimentation occurs in these tanks. Floating residues are heat-treated in order to enhance oil removal and recovery. After pH adjustment, the waste stream flows to an aerated pond for biological degradation. Mean hydraulic residence time for biological treatment is 8 hours. Close supervision is required due to the marginal treatability of the waste. Subsequently, the pond effluent is dosed with alum for coagulation and precipitation. Flow then is to sand filters followed by activated carbon columns. Final pH adjustment is made if needed. When operating properly, organic removals are good, i.e. average BOD reductions from 2,280 mg/l to 80 mg/l.

Reed and Hemphill (25) have examined an electrochemical system for treating tank truck cleaning wastes. The system uses flow equalization followed by an electrostatic treater, and an electrolytic treater where the bulk of effective treatment takes place. Effluent from the electrolytic treater partially flows to a clarifier and partially is recycled. In the recycle stream, lime addition raises pH to 10.5 to 11.0, then flows through a second electrostatic treater and then back to the plant head end. Detention times for the electrolytic treater and clarifier are 45 minutes and 5.7 hours, respectively. Effluent quality from the treatment method is variable, and appears to be dependent upon retention of a high solids concentration in the electrolytic reactor. Even though the method appears to work, failure to produce a consistently acceptable effluent limits its usefulness.

In 1974, EPA proposed effluent guidelines for tank truck wastewaters. Tank truck carriers claimed that the technology recommended by EPA had not been demonstrated specifically for the tank truck industry; hence, they requested a demonstration of a technically and economically viable process before effluent guideline promulgation. Such a demonstration was approved and funded by EPA (21).

Tank trucks usually are washed by hot caustic solutions which are recycled. Rinse waters, on the other hand, require processing before discharge. Prevailing methods for treatment are: 1) air flotation followed by biological treatment, 2) physical/chemical treatment, 3) bleed-in biological systems, and 4) the proposed EPA demonstration system. The proposed EPA demonstration system includes the following sequence of unit operations (21):

- oil separation
- chemical coagulation and pH adjustment
- air flotation
- mixed-media filtration
- carbon adsorption
- rotating biological filter treatment
- sedimentation.

Initial results for this treatment train were favorable, and were the basis for demonstrating the state-of-the-art system proposed by EPA.

O'Brien (27) described this work on tank truck wastewater treatment in a recent EPA report. Using the same treatment train described in reference (21), O'Brien obtained long term removals of COD at 90 percent, and removals of 99 percent for oils and greases and phenolics. The overall cost for treatment was reported as $12.92/1000 liters ($48.92/1000 gallons). The innovations examined were substituting ozone or ozone/ultraviolet for activated carbon, and the use of an anaerobic filter instead of the rotating biological filter. Feasibility of both unit operations was proven. An attempt to ascertain removals of various toxic organic materials was unsuccessful and inconclusive. O'Brien (27) concluded: "Results of the testing indicate potential wide application of the technology employed recognizing transferability to many other mixed waste treatment problems. Some of these areas might include railroad tank car cleaning, *drum cleaning and recycling*, or the treatment of other mixed chemical wastewaters resulting from off-site waste hauling and treatment operations." (Emphasis added.)

In an earlier work (7), it was noted that railroads commonly use ponds or lagoons to treat wastewaters.

Chian and Gupta (19) showed on a pilot scale that reverse osmosis and ultrafiltration had promise for treating wastewater from vehicle and aircraft washracks. Methods they explored could produce aqueous streams capable of being recycled. Criteria established for recycle streams were: total dissolved solids -

1,000 to 1,500 mg/l; and, total organic carbon - 50 to 100 mg/l. The best alternative was: a) chemical precipitation followed by reverse osmosis treatment of blowdown water for TDS removal, and b) membrane ultrafiltration of oily wastes then reverse osmosis of blowdown water. The ultrafiltration step produced the following results: total dissolved solids influent - 810 mg/l, effluent - 320 mg/l; total organic carbon influent - 701 mg/l, effluent - 19 mg/l.

More recently, Wahl *et al*. (26) discussed use of ultrafiltration for several major applications, one of which is the treatment of oily waste discharges from tank car cleaning operations. The principal purpose of ultrafiltration was removal of emulsified oil and suspended solids from cleaning wastestreams. Due to the nature of the waste solutions, noncellulosic membranes capable of withstanding high temperature and pH were used. The effort was a compendium of operations data from several types of industries sharing similar waste characteristics.

In most cases, ultrafiltration processing (usually semibatch operation) was preceded by equalization and settling tanks for free oil removal. Removing free oil upstream markedly improved membrane life. The permissible ranges of operation for pH and temperature were 2 to 13 and 40°C to 49°C (40°F to 120°F) using the noncellulosic membrane. Optimal system conditions were 38°C to 43°C (100°F to 110°F) and pH from 8 to 10. Average membrane life is two to three years.

Emulsified oil removal by ultrafiltration is excellent. Figures by Wahl et al. (26) showed average influent concentrations of 32,000 mg/l, and 61 mg/l in the permeate stream. (Low molecular weight solvents and organics are not rejected by the membranes, and thus, also appear in the permeate). The oil concentrate stream contains 39 percent oil. Four options for disposal of concentrate commonly are employed:

1) Direct burning - the ultrafiltration concentrate (35 to 40% oil) is mixed with tramp oils and No. 2 fuel oil.

2) Gravity separation - ultrafiltration concentrate is settled for 3 to 5 days, and the oil phase is burned directly with the water phase reprocessed.

3) Acid cracking - ultrafiltration concentrate is heated to 71°C to 82°C (160°F to 180°F) and acidified to pH of 2; the oil phase is burned and the water phase is neutralized and reprocessed.

4) Contract hauling - the ultrafiltration concentrate is sold or given away (in about half the cases), or is hauled for a fee.

Costs for treating oil wastes range from $0.53 to $20.08/1000 liters ($2.00 to $76.00 per 1000 gallons), not counting any credits taken from oil recovery.

Steel Drum Cleaning--

Levy (28) points out that there are three basic alternatives in dealing with wastewater generated in a drum reconditioning plant: 1) pretreatment in preparation for discharge into a publicly owned sewerage system, 2) treatment and direct discharge into a receiving water body, and 3) complete recycle and reuse. Table 23 confirms that these are the three main options. Landfilling and evaporation are infrequently used, representing less than 3 percent for caustic solutions and about 10 percent for rinse water. Moreover, landfilling is less desirable since promulgation of RCRA regulations. In Table 38, Levy compares various aspects of wastewater disposal for the three leading alternatives.

It is possible to have more than one method in a single plant if caustic stripper solutions and rinse water streams are segregated. Only about a third of reconditioning plants segregate wastewater streams. Separating caustic and rinse water increasingly is necessary to achieve governmental regulations for any of the three major disposal alternatives. The trend appears to be toward reuse and recycle of caustic stripper solutions. All three methods are used for rinse water.

Levy (28), in Table 39, enumerates some of the wastewater treatment processes having potential for use in drum reconditioning plants. Many currently are in use at several plants. He likewise correctly points out that oil drums constitute the single largest source of drums bound for reconditioning. In Table 40, he lists the efficiences of several oil/water separation processes. Presumably, these processes would be used to remove oil present because of clingage which remains in the drums after siphoning or emptying for oil recovery.

Note in Table 40 that emulsified oil removals increase substantially when chemicals are used, e.g. in conjunction with air flotation or for coagulation and sedimentation. Thus, while good oil removals are achieved, sludge volumes increase.

Levy (28) emphasizes the desirability of achieving zero discharge (complete reuse and recycle), and notes that three elements are important to do so. These are: 1) source control, 2) water conservation and reuse, and 3) extensive wastewater treatment and polishing. Specific guidelines or "principles" for achieving zero discharge are given in Table 41.

Kinman _et_ _al_. (22) made a detailed bench-scale investigation of several processes for treating wastewater generated during steel drum reconditioning. Methods were both physical-chemical and biological types. The physical-chemical treatment bench-scale pilot plant used pH adjustment, coagulation addition and mixing, flocculation, and sedimentation, activated carbon

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TABLE 38

WASTEWATER DISPOSAL COMPARISON SUMMARY
(from Reference No. 28)

	Pretreatment	Treatment and Discharge	Zero Discharge
Degree of Treatment (Cost)	Low	Medium	Medium
Government Regulations	Medium	High	Low
Flexibility	Medium	High	Low
Environmental Effect	Medium	High	Low
Residuals Production	Medium	Medium	High
Technical Feasibility	High	Low	Medium
Reuse Potential	Low	Medium	High

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TABLE 39

WASTEWATER TREATMENT PROCESSES FOR A DRUM RECLAMATION FACILITY
(from Reference No. 28)

Process	Description
● Gravity Separation - API separators - Parallel plate separators	Separate free oils by skimming
● Rotational Separation - Vortex separators - Centrifuges - Rotary drum separators	Enhance gravity sedimentation to improve efficiency with smaller oil globules
● Neutralization	Addition of acid to neutralize the caustic effluent
● Chemical Addition - Chemical coagulants - Flocculants	Improve mechanical separation by breaking up emulsions and enlarging solids for settling
● Physical Separation Enhancement - Dissolved air flotation - Coalescers - Heating	Supplement other systems to remove free and emulsified oil
● Filtration - Adsorption filters - Mechanical strainers - Ultrafiltration	Passage of wastewater mixtures after separation through media that trap contaminants

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TABLE 40

EFFICIENCY OF PRIMARY OIL/WATER SEPARATION PROCESSES
(from Reference No. 28)

Treatment Method	Process Efficiency (Percent Removal) Free Oil	Process Efficiency (Percent Removal) Emulsified Oil
Gravity separation	60 - 99%	N/A
Gravity separation with demulsifier	60 - 99%	10 - 30%
Air flotation without chemicals	70 - 95%	10 - 40%
Air flotation with chemicals	75 - 95%	50 - 90%
Chemical coagulation and sedimentation	60 - 95%	50 - 90%

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TABLE 41

PRINCIPLES FOR ACHIEVING ZERO WASTEWATER DISCHARGE IN A DRUM RECLAMATION FACILITY

(from Reference No. 28)

- Empty drums thoroughly to intercept waste material before entering the operation, i.e., intercept contaminants.
- Manage the types of incoming drums to schedule similar waste drums being cleaned at the same time.
- Operate an efficient closed loop caustic cleaning system.
- Identify and maintain minimum flow and water quality needs for each plant area: hot rinse, cold rinse, underwater pressure testing, cleanup, boilers, compressor cooling.
- Cascade water use from higher to lower quality needs.
- Identify and design wastewater treatment systems to satisfy the plant needs and provide a closed loop.
- All equipment must be well operated and maintained by a trained staff.
- Residuals must be segregated and managed in the land or air media.

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adsorption, and ion exchange. Kinman *et al*. (22) showed the following COD removals: coagulation - 79.3%; coagulation + carbon adsorption - 97.8%; coagulation + ion exchange - 84.2%; and coagulation + carbon adsorption + ion exchange - 97.8%. Note that the ion exchanger removed no organics subsequent to carbon adsorption.

On the basis of the pilot experiments, Kinman *et al*. (22) concluded that a proposed physical-chemical treatment plant as shown in Figure 14 would adequately treat wastewater from a drum reconditioning plant. The process envisioned burning of grease in a drum incinerator, and thickened sludge disposal at a landfill or other disposal site. The authors of the paper (22) concluded that the cost of this treatment plant may be well beyond the capabilities of small drum reconditioners.

Kinman *et al*. (22) showed that drum reconditioning wastewater could be treated successfully by a completely mixed batch activated sludge system. Conditions for successful treatability included: pH reduction to 7.8, nitrogen addition to a COD:N:P nutrient ratio of 300:5:1, and a loading rate of 125 lb COD/day/1,000 cu.ft. The most important factor in initiating aerobic treatment was pH reduction to at least 8.5 , while the most important factor in maintaining treatment was proper nitrogen concentrations.

Nipper (29) demonstrated the technical feasibility of induced air flotation for removing emulsified oil at a drum reconditioning plant. Work was performed to investigate the alternative of removing oil at the plant as opposed to paying the public sewer system surcharge. Research showed that best oil and grease removals were obtained in the pH range 3.6 to 6.2; using 10 mg/l of Tretolite F-46$^{(TM)}$ as the chemical additive; and a 10 minute retention time. Removals were about 98 percent. Despite technical feasibility, Nipper concluded that installation of an induced air flotation facility at the drum plant was not justified economically.

A drum plant in the United Kingdom uses an ICI electroflotation treatment system. The system employs a sacrificial aluminum anode to generate small bubbles electrolytically which aid in flotation. The electroflotation step is subsequent to three phase separation of oil (which is burned as fuel), sludge (which is hauled to a landfill), and subnatant liquor. This liquid stream passes to the fiberglass electroflotation cell where the pH is adjusted to 4 using either HCl or H_2SO_4. Electrical current causes the bubble formation which floats oil and solids to the liquid surface from which they are skimmed. After pH readjustment to 7 to 8, the treated liquid flows to a final settling tank prior to sewer discharge.

A Japanese reconditioner has tried an electrofiltration

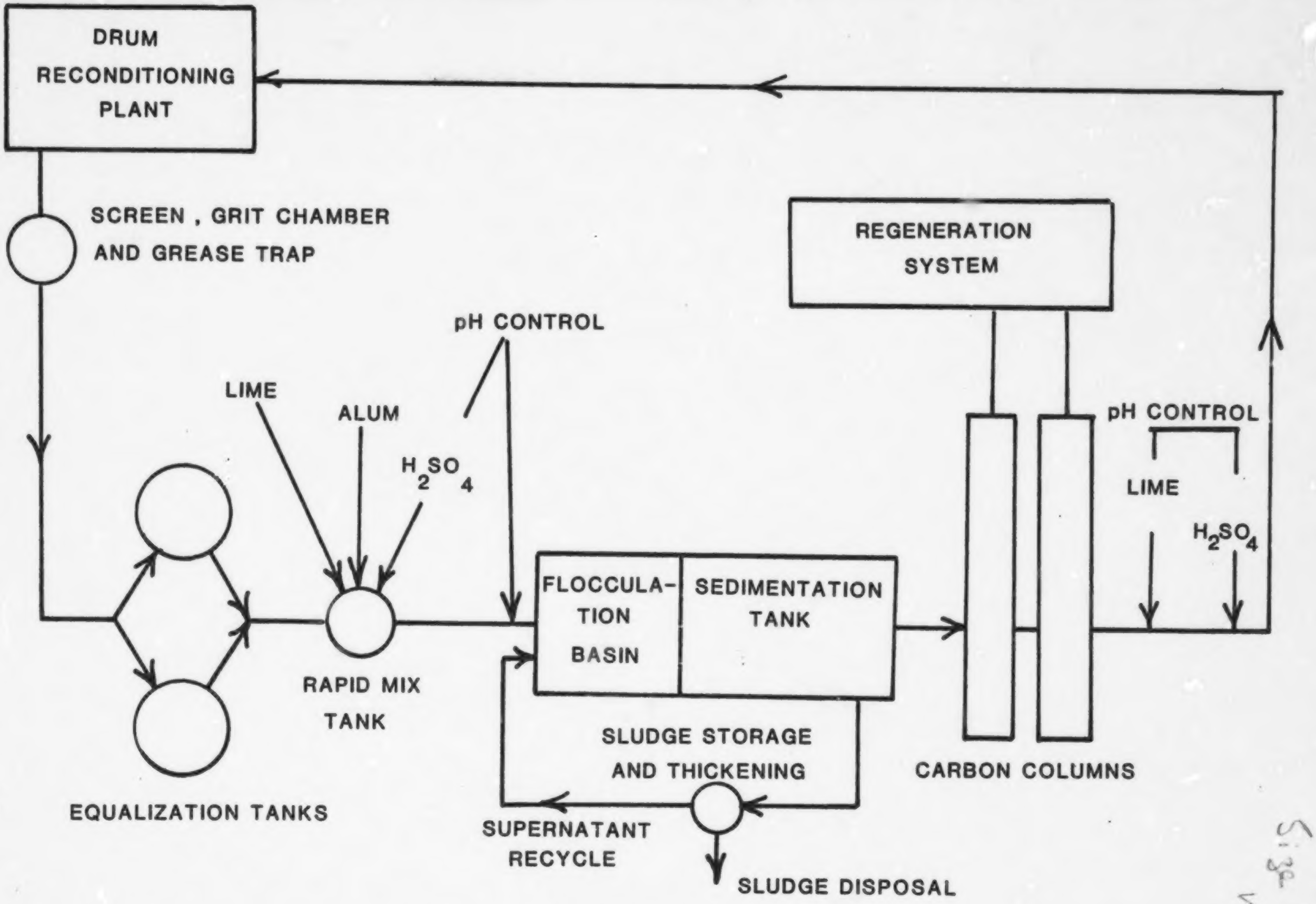
DRUM RECONDITIONING PLANT
SCREEN , GRIT CHAMBER AND GREASE TRAP
REGENERATION SYSTEM
pH CONTROL
LIME
ALUM
H_2SO_4
pH CONTROL
LIME
H_2SO_4
FLOCCULA-TION BASIN
SEDIMENTATION TANK
RAPID MIX TANK
SLUDGE STORAGE AND THICKENING
CARBON COLUMNS
EQUALIZATION TANKS
SUPERNATANT RECYCLE
SLUDGE DISPOSAL

Figure 14 . PROPOSED WASTEWATER TREATMENT PLANT (Reference No. 22)

Size Reduction needed

treatment method. It is complex in terms of its equipment, using a wire grid system, and ancillary processes, e.g. activated carbon. Results of the process were not reported.

The foregoing material was intended to give a general overview of wastewater treatment from the perspective of a reconditioner (28), indicate some research performed on drum reconditioning wastes (22)(29), and describe some unique treatment methods used abroad. The remainder of this section will be devoted to findings regarding processes and equipment for wastewater treatment as determined in the NABADA survey.

About 10 percent of the reconditioners queried in the NABADA survey claimed to use innovative pollution control systems. Approximately one-fifth of these simply were using state-of-the-art wastewater treatment systems, albeit somewhat sophisticated. Others were in the process of making custom alterations of existing treatment or burning units, while about 60 percent of those claiming to employ innovations were using unique technology. For example, one reconditioner allowed drum drainage to separate into three phases (floating, liquid, and settleables), and then sent the liquid phase to a settling tank from which discharges were made into a publicly owned sewerage system. Others regarded closed cycle systems as being innovative. Finally, one reconditioner recently developed a novel sludge drying system. This will be described later in this section.

About 55 percent of all reconditioning facilities have in-place or under construction their own wastewater treatment plants. Interestingly, none of the responders to the NABADA survey use either biological treatment or activated carbon adsorption. Equipment used by reconditioners, most of which is related to pollution control, is shown in Table 42.

Other equipment mentioned in the NABADA survey were coalescing plate separators for oil removal, oil skimmers, and packaged wastewater treatment systems. One reconditioner simply stated that dilution served as the waste treatment method. Two manufacturers in particular have a significant number of installations using their pollution control equipment. One is Blace Filtronics, Inc., Derby, Connecticut. Blace Filtronics manufactures a diatomaceous earth filter for use mainly on caustic wash solutions. The filter can be used batchwise or continuously. In a typical plant about 4.5 to 9.1 kg (10 to 20 pounds) of diatomaceous earth are used daily, and backwashing occurs once to twice a day. As of February 1980, Blace Filtronics was used in 12 U.S. and one Canadian reconditioning plants.

The other manufacturer, Envirodyne Company, Inc. of Arlington Heights, Illinois, markets both caustic clarification and wastewater treatment equipment. The caustic cleaning system depends upon air flotation. It does not use settling or filtration

TABLE 42

WASHING PLANT RECONDITIONING EQUIPMENT

Equipment Type	Percentage of Reconditioners Using Such Equipment
Flushomatics(TM)	26.8
Caustic Filters	31.7
Vacuum Drying Systems	73.2
Automated Flushers	48.8
Automated Upenders	80.5
Oil/Water Separators	61.0
Screens for Gross Particle Removal	56.1
Dissolved Air Flotation	17.1
Flocculation/Sedimentation	34.1
Coagulation Feeders	7.3

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for further clarification. The manufacturer claims: "dirty caustic enters at one side of 4-cell clarifier and is cleaned up four times as it travels from one cell to the next. A portion of clarified caustic is pressurized along with air. The recycled caustic with air is distributed among four cells to help float gummy solids, oils, grease and suspended solids. Scum from four cells is collected automatically by wipers in a common trough and is discharged by gravity for disposal. Clarified caustic goes to the outlet box from where it can be reused in submerger or flushers." In smaller plants, this equipment can be connected directly to flushers or submergers. In large plants, dirty and clean caustic holding tanks may be required.

The Envirodyne wastewater treatment plant usually is used for rinse water. It employs dissolved air flotation and inclined plate settling to clean the rinse water. Chemical coagulation (alum) and neutralization are preliminary treatment steps.

Endless belt oil skimmers are used frequently for oil recovery. Lime sometimes is utilized to demulsify oil.

In general, reconditioners tend to fabricate much of their own pollution control systems, wherever possible. Several plants visited as part of this project had caustic clarification and rinse water treatment systems which did not use any commercially available components. Similarly, many plants use different sequences of unit operations. Figures 15 through 17 illustrate treatment processes for three reconditioning plants. Note the differences in unit processes and the objectives of each plant. Plant No. 1 (Figure 15) uses a rather simple system focusing on oil removal. The outstanding aspect of this plant is use of the drum furnace to burn clarifier sludge. In Plant No. 2 the drum incinerator is used, but for purposes of burning recovered oil. There is no separate treatment of caustic and rinse water streams. Plant No. 3 segregates caustic and rinse waters. It represents one of the most advanced wastewater pollution control systems in the industry.

Most wastewater treatment plants used by reconditioners appear to be variants of those shown in Figures 15 through 17.

Solids and Residuals

Most reconditioners use landfills to dispose of sludges, ash, and other solid residues. Often contract haulers will take the material to the landfill. Burning is becoming an increasingly attractive and necessary alternative because of stringent RCRA regulations recently promulgated. Some reconditioners view the trend as an opportunity to develop their own separate sludge incinerators with the possibility of accepting outside sludge to be burned for a fee. However, most burning of solids now is done in drum furnaces.

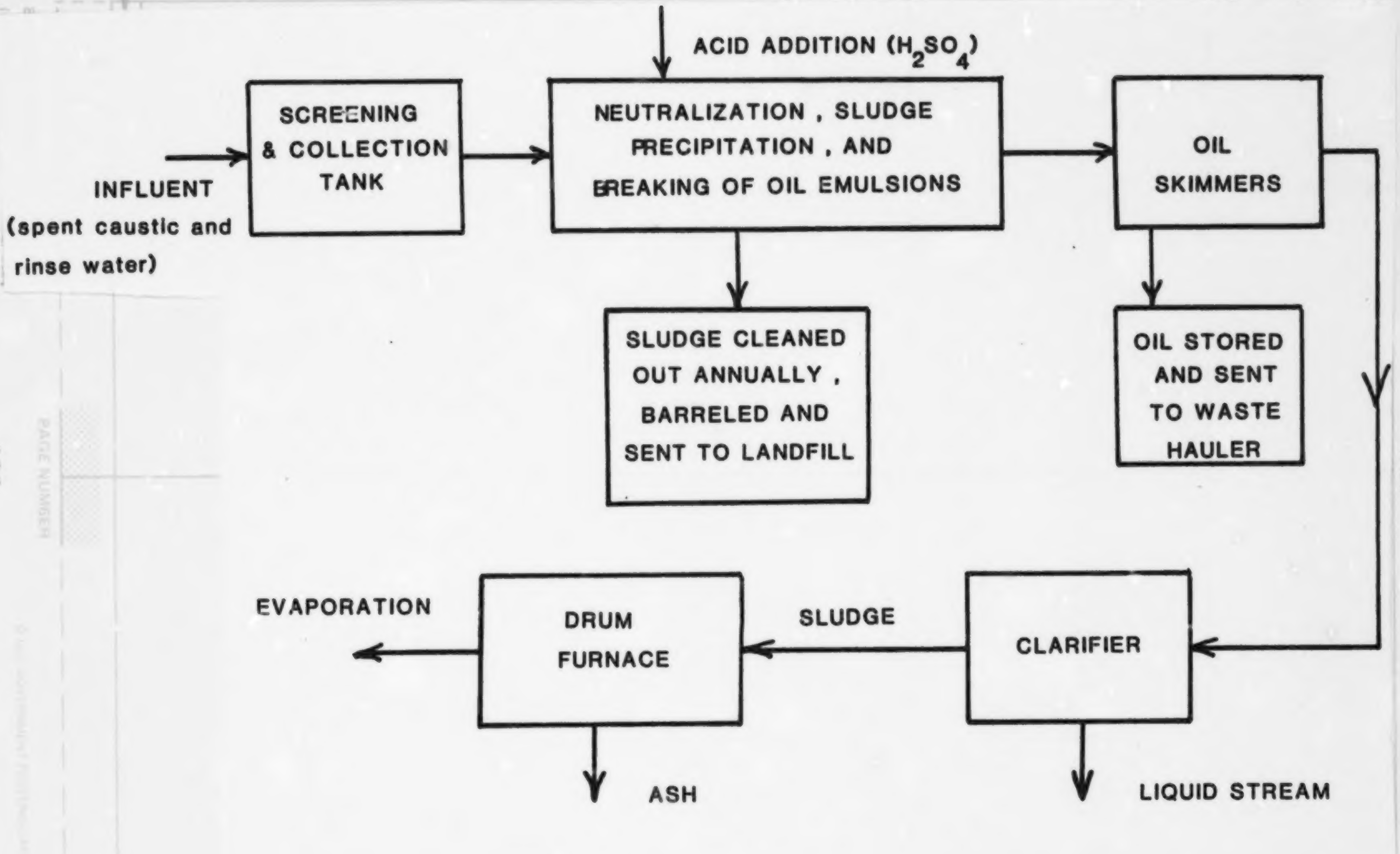
ACID ADDITION (H_2SO_4)
INFLUENT (spent caustic and rinse water)
SCREENING & COLLECTION TANK
NEUTRALIZATION , SLUDGE PRECIPITATION , AND BREAKING OF OIL EMULSIONS
OIL SKIMMERS
SLUDGE CLEANED OUT ANNUALLY , BARRELED AND SENT TO LANDFILL
OIL STORED AND SENT TO WASTE HAULER
EVAPORATION
DRUM FURNACE
SLUDGE
CLARIFIER
ASH
LIQUID STREAM

Figure 15 . WASTEWATER TREATMENT , PLANT NO . 1

FIGURE 16. WASTEWATER TREATMENT, PLANT NO. 2

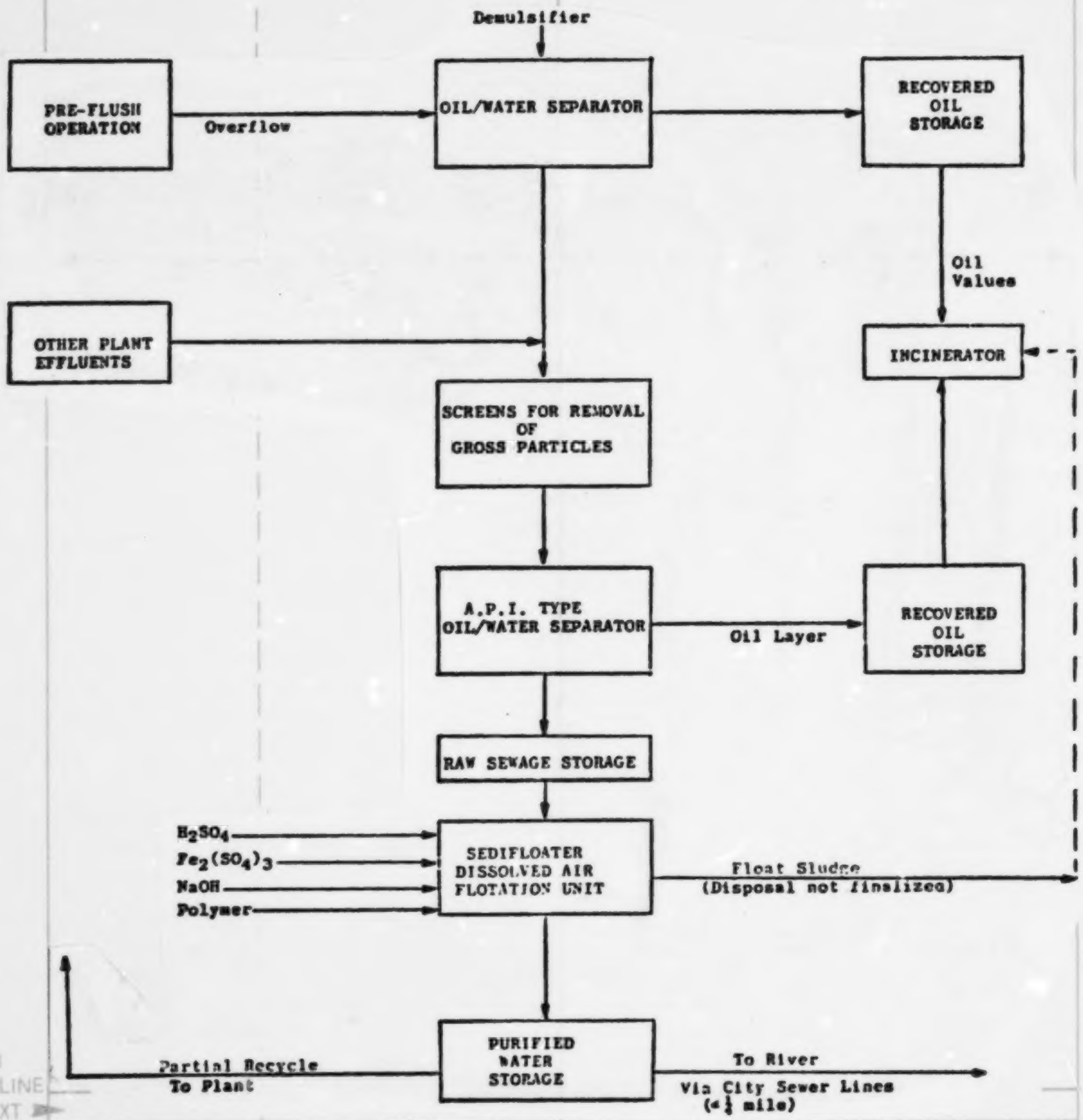
Demulsifier
PRE-FLUSH OPERATION
Overflow
OIL/WATER SEPARATOR
RECOVERED OIL STORAGE
Oil Values
OTHER PLANT EFFLUENTS
INCINERATOR
SCREENS FOR REMOVAL OF GROSS PARTICLES
A.P.I. TYPE OIL/WATER SEPARATOR
Oil Layer
RECOVERED OIL STORAGE
RAW SEWAGE STORAGE
H2SO4
Fe2(SO4)3
NaOH
Polymer
SEDIFLOATER DISSOLVED AIR FLOTATION UNIT
Float Sludge (Disposal not finalized)
PURIFIED WATER STORAGE
Partial Recycle To Plant
To River Via City Sewer Lines (≈½ mile)

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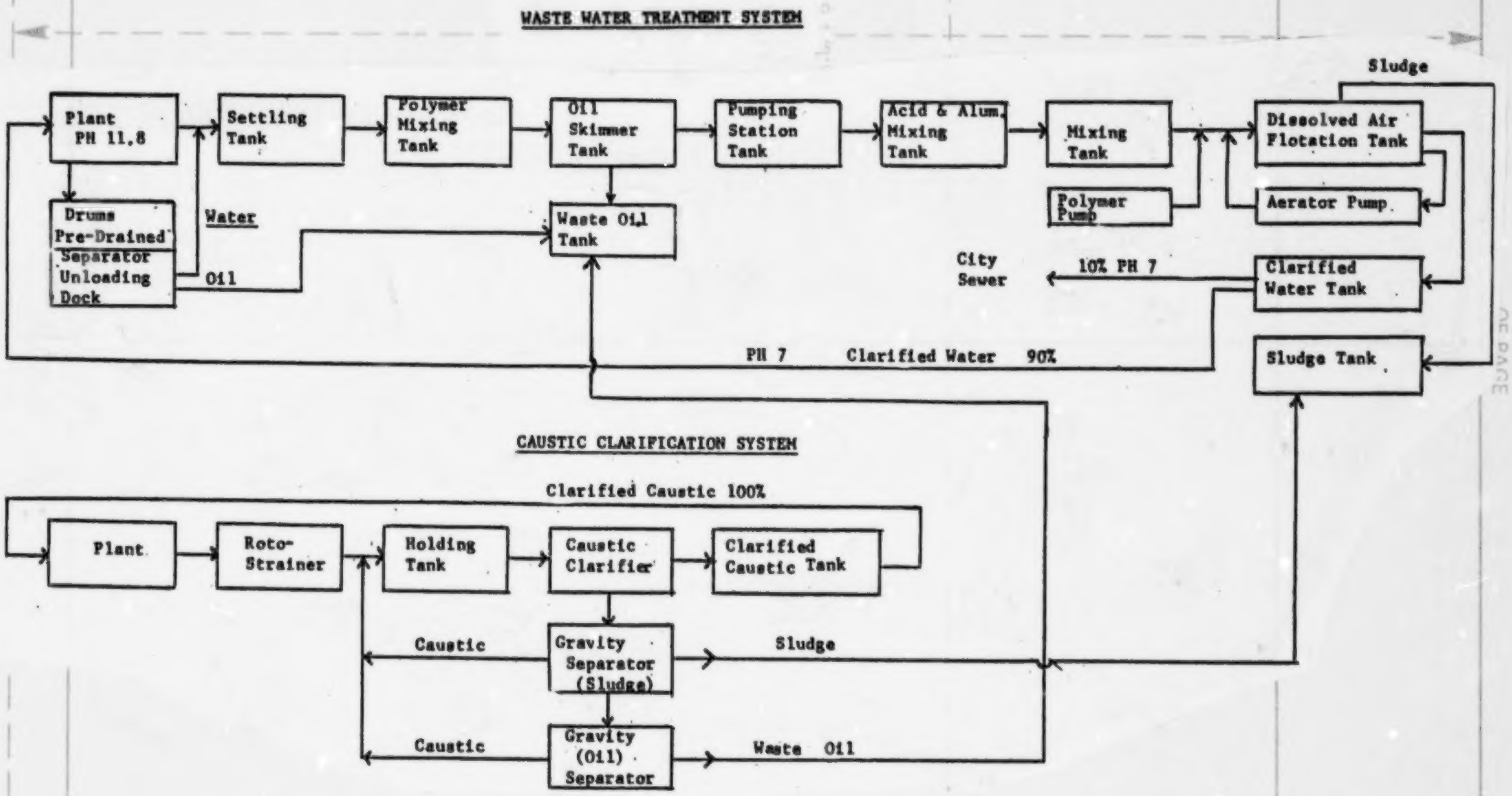
FIGURE 17. WASTEWATER TREATMENT, PLANT NO. 3


WASTE WATER TREATMENT SYSTEM
Plant PH 11.8
Settling Tank
Polymer Mixing Tank
Oil Skimmer Tank
Pumping Station Tank
Acid & Alum. Mixing Tank
Mixing Tank
Dissolved Air Flotation Tank
Sludge
Drums Pre-Drained Separator Unloading Dock
Water
Oil
Waste Oil Tank
Polymer Pump
Aerator Pump
City Sewer
10% PH 7
Clarified Water Tank
PH 7 Clarified Water 90%
Sludge Tank
CAUSTIC CLARIFICATION SYSTEM
Clarified Caustic 100%
Plant
Roto-Strainer
Holding Tank
Caustic Clarifier
Clarified Caustic Tank
Caustic
Gravity Separator (Sludge)
Sludge
Caustic
Gravity (Oil) Separator
Waste Oil

147

Using drum furnaces to burn sludges has disadvantages. Temperature excursions can be harmful to the furnace, and the likelihood of air pollution control violations increases substantially unless rigorous feed controls are instituted.

In the United Kingdom, a reconditioner plans to use a fluidized bed incinerator, fueled by sludges and other residuals, to generate process steam for the plant. This example is illustrative of an emerging trend in the industry. Many reconditioners envision using rejected organics to fuel plant boilers. One major reconditioner currently is drawing up specifications for bids to install such a facility.

Costs of fuel have stimulated interest in waste heat usage. Full potential of this area has yet to materialize. Some reconditioners envision using waste heat to raise the temperature of caustic solutions. One innovative application involves constructing a sludge dryer consisting of an inclined chain belt enclosed in a steel duct. Hot gases (538°C or 1000°F) from the afterburner are in contact with the sludge for one to two hours. The dried sludge is landfilled.

There are numerous companies offering contract incineration, hauling, treatment, landfill, and storage services. Reconditioners should use extreme care in selecting a qualified disposal firm.

OPERATING PROCEDURES

Clearly, reconditioning drums containing certain types of materials could be helped greatly by using removable liners. Such a liner was described in an article in Adhesive Age (30). It was claimed that reconditioning costs were cut in half by using a removable plastic drum liner. A problem sometimes is that users fail to remove the liner after the drum is empty, usually because the liner is punctured and contents have caused it to stick to the container side. These liners are used only in open head drums. Hence, the stuck liners are burned, sometimes causing flashing and flaring, and occasionally burning dragout. Solutions possibly could be to reject drums with ruptured linings, require removal of liners before receipt, or removal by the reconditioner at an extra charge.

Certain reconditioners urge preflushing at least some of the more troublesome drums before burning in order to prevent excesssive smoke emissions. An additional benefit of preflushing before incineration is reduced possibilities of flaring, flashback, and temperature excursions. Flaring (the primary cause of smoke emissions) also can be reduced using "starved-air combustion." It generally is acknowledged that most air pollution incidents are related to visible emissions, and these are best controlled by operator judgment.

Cascading water uses is a helpful technique. For example, spent rinse water can be used for drum quenching at the furnace exit. In addition to helping to evaporate spent rinse water, it provides a cleaner stream for makeup. Then, the quench water can be reused in an afterburner scrubber, if one is used. Use of rinse water for furnace quenching is an important step toward achieving a complete recycle and zero discharge system. One manufacturer suggests that evaporation in furnace quenching may not be sufficient to get rid of all the spent rinse water desired. Moreover, a solution is not available if the plant does not both burn and wash. The suggested solution to caustic buildup in rinse waters would be routine blowdown and evaporation. Another possibility for use of spent rinse water is for preflush makeup.

Japanese reconditioners successfully have used acid treatment of sludge to separate oil, sludge, and alum for reuse. This method supposedly enhances the quality of oil, making some suitable for burning either directly or when mixed with fuel oil. Many U.S. reconditioners combine oil and scum layers with fuel oil for burning.

Interest has been shown in using rotary kilns to burn residues in order to make steam, hot water, and supply building heat. It is envisioned that the rotary kiln air pollution control devices will include an afterburner and boiler, scrubber, and baghouse. The rotary kiln, if operated at 1093°C (2000°F) with a retention time of one second, would be expected to destroy completely all organics encountered in drum reconditioning. Heat reuse is a continuing interest within the industry.

Some reconditioners have used water-based paint to reduce air pollution from painting booths and baking ovens. However, such paints do not work too well as drum finishes. However, such finishes continue to improve in quality.

As a point of interst, drum service areas yielding favorable economic returns are 48 km (30 miles) in radius in England. By contrast, typical service areas in Canada are about 320 km (200 miles).

The most common need and area of improvement cited by reconditioners, in terms of easing potential environmental problems, is good househeeping. Attention to housekeeping practices varies widely from plant to plant.

DISPOSAL PRACTICES

Municipal pretreatment standards have caused sharp movement toward reuse and recycle of caustic stripping solutions and rinse waters. Currently, about 53 and 35 percent of caustic solutions and rinse waters are recycled and reused, respectively. Events point to greater pressure to upgrade pretreatment, and hence give further encouragement to reuse. The principal focus of environmental pollution control for the foreseeable future will be management of sludges and solid residues. The industry recognizes the importance of dealing with these wastes effectively, especially in view of their major pollution potential. For example, in terms of oily wastes alone, a washing plant which processes 3,000 drums/day has a waste population equivalent of from 25,000 to 50,000.

Reconditioners visualize the following disposal options as being the most viable for sludges high in organics:

1) sanitary or secured landfill
2) incineration
3) pyrolysis
4) low temperature oxidation
5) chemical conversion
6) contract disposal.

Presently, landfilling, burning and contract disposal account for 84.0 percent of wet sludges, 94.3 percent of dry sludges, and 96.8 percent of ash. Most contract disposal is by landfill. Whether or not a sanitary or secured landfill is used depends upon the hazardous nature of the waste. Specific criteria are defined in RCRA regulations.

Burning options are distinguished by the temperature ranges (pyrolysis, about 1093°C or 2000°F; incineration, 649°C to 871°C or 1200°F to 1600°F; and low temperature oxidation, less than 538°C or 1000°F). Pyrolysis typically is used for wastes which have high hazard and toxicity potentials.

Chemical conversion usually involves oxidation or reduction reactions, but precipitation may be involved. This method is used infrequently.

Contract disposal can involve any of the options listed above. It usually refers to landfilling.

Some new disposal methods have been described before, e.g. rotary kiln and fluidized bed furnaces. An Australian reconditioner currently uses a wet bed incinerator for sludge disposal. Research studies have been made for the feasibility of encapsulating sludge in plastic, as well as microwave destruction. It appears that research methods investigated to date are far from application. Japanese use of rotary kiln burning is rapidly increasing. Table 43 shows the relative usage of various sludge disposal methods in Japan during 1976.

In summary, industry trends are strongly toward recycle and reuse of aqueous streams and burning of solid residues.

TABLE 43

JAPANESE SLUDGE DISPOSAL METHODS
(for year 1976)

Method	Percentage of Reconditioners Using Method
On-Site	
Dewater and reclaim	28
Dewater, burn and reclaim	12
Contracted Off-Site	
Filter press dewatering	42
Sand bed dewatering	3
Screw press dewatering	3
Rotary kiln burning	12

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REMOVAL EFFICIENCIES

There is a dearth of information on wastewater treatment plant removal efficiencies. In fact, for the NABADA survey only seven reconditioners responded to the question which inquired aabout removal of a variety of pollution parameters. Table 44 reports the results of that question. Recognize, however, that the few responses do not lend great credibility to the data.

Table 45 lists effluent concentrations for a Japanese treatment plant. These concentrations are well within governmental discharge requirements.

TABLE 44

WASTEWATER TREATMENT PLANT EFFICIENCIES*

Parameter	Average Removal (%)	No. of Observations	Range Min.	Range Max.
BOD	68.2	2	47	89.3
COD	95.4	1	-	-
Suspended Solids	84.4	6	60	95
Oil and Grease	91.3	6	78	100
Phenol	-	-	-	-
Cyanides	-	-	-	-
Lead	84.7	3	67	97.0
Zinc	80.1	3	62.3	90
Nickel	-	-	-	-
Copper	90	1	-	-
Chromium	73.7	3	41	90
Cadmium	-	-	-	-
Pesticides	-	-	-	-
TOC	-	-	-	-
Volatile Organics	-	-	-	-
pH change	12.0 to 7.3	5	7	13.2

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* All parameters for which information was requested in the NABADA survey are listed even though there was no data obtained.

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TABLE 45

DISCHARGE CONCENTRATIONS FROM A JAPANESE WASTEWATER TREATMENT PLANT

Parameter	Concentration (mg/l)
pH (units)	7.1
Conductivity (in mv/cm)	2,500
Alkalinity (as $CaCO_3$)	100
Hardness (as $CaCO_3$)	30
COD	60
BOD	30
Suspended Solids	4.5
Hexane Extractables	5.0
Chlorides	700
Sulfates	200
Silica	14
Total Iron	0.3
Sodium	500
Potassium	0.9
TDS	1,800

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SECTION 7

POLLUTION CONTROL COSTS

A previous section has discussed the costs of new and reconditioned drums. This section focuses upon those costs to reconditioners related to pollution control.

SEWER SURCHARGES

Drum reconditioning washing plants often discharge to publicly owned wastewater treatment plants. In the past, industrial dischargers usually were charged only on the basis of effluent flows. More recently, surcharges have been established which assess reconditioners based upon quantities and concentrations of pollutant parameters. Biochemical oxygen demand (BOD) and total suspended solids (TSS) are the parameters used most commonly for surcharges. Chemical oxygen demand (COD), nitrogenous oxygen demand (measured as total Kjeldahl nitrogen), grease, phosphorus, phenols, and pH also have been used for assessments.

Surcharges usually are added to volume charges. Table 46 shows the volume cost factor in cents per 1000 gallons for several actual installations. (Typically these factors are expressed in English units). The table also lists cost factors for BOD, TSS, TKN, and COD (in cents per pound) as applied in several municipal systems. Other costs cited include: minimum bills, connection charges, surcharge credits, and infiltration-inflow fees. It is common to apply the surcharge only after typical domestic sewage concentration limits are exceeded. Hence, typical sewage concentrations are excluded or subtracted from the reconditioner's effluent concentrations. The rationale is that volume charges are designed to cover costs in the normal influent concentration range; whereas, surcharges cover costs for extra treatment required by higher strength wastes. Some plants, however, do not have an exclusion value.

Some municipalities express their surcharge requirements as formulae. Table 47 gives three actual examples of sewer surcharge formulae. Note in each case that the surcharge is beyond costs based upon volume of flow. The examples are similar.

In order to determine the comparability of surcharges around the U.S., eleven example surcharge methods were normalized for a

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TABLE 46

BASES FOR SEWERAGE SURCHARGES

	Volume Cost Factor (¢/1000 gal)	BOD Cost Factor (¢/pound)		TSS Cost Factor (¢/pound)		TKN Cost Factor (¢/pound)		COD Cost Factor (¢/pound)	Other Costs
			less exclusion (mg/1)		less exclusion (mg/1)		less exclusion (mg/1		
	26.7	-		2.0	0	-		2.0	-
	-	4.3	305	3.3	400	-		-	-
	11	3.0	0	7.9	0	-		-	Sewer Connection Charge = $4.53/mo.
	92	5.6	300	5.6	300	-		-	Minimum Bill= $25.00/mo.
	69.3	7.9	250	8.6	250	-		-	-
	-	4.6	240	3.1	300	5.5	25	-	If a pollutant is less than 80% of the exclusion value, then there may be a credit against the total surcharge.
	25.4	-		-		-		-	Flat infiltration - inflow charge=25.4¢/1000 gal/mo.
Ave	44.9	5.1	219	5.1	208				

TABLE 47

SEWER SURCHARGE FORMULAE

FORMULA NO.1

$$S.F. = \frac{a\ (BOD-300)}{300} + \frac{b\ (SS-300)}{300} + \frac{c\ (CD-25)}{25} + \frac{d\ (P-30)}{30}$$

Where: S.F. = Surcharge factor
BOD = Biochemical Oxygen Demand (mg/l)
SS = Suspended Solids (mg/l)
CD = Chlorine Demand (mg/l)
P = Phosphorus (mg/l)
a = Proportion of cost to treat unit of BOD (0.3)
b = Proportion of cost to treat unit of SS (0.3)
c = Proportion of cost to treat unit of CD (0.1)
d = Proportion of cost to treat unit of P (0.2)

FORMULA NO. 2

$$SC = 0.0624\ V\ \{a(BOD-200) + b(TSS-250) + c(P-10)\}$$

SC = Pollutant strength surcharge fee in dollars
V = Volume of waste discharged in 100 cubic feet
a = Surcharge rate for BOD ($0.083/pound)
b = Surcharge rate for TSS ($0.084/pound)
c = Surcharge rate for P ($1.34/pound)
0.0624 = Conversion factor (1000 cubic feet to million pounds)

FORMULA NO. 3

$$ESMC = (Vm-P) \times \$0.3035 + (B \times \$0.1638) + (T \times \$0.1844)$$

ESMC = Extra strength monthly charge
Vm = Metered water volume in thousand gallons
P = Product usage factor (use 8,000 gallons)
B = $(BOD-200) \times V_T \times 8.34$
T = $(TSS-250) \times V_T \times 8.34$
V_T = Metered water volume in million gallons

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typical reconditioning plant. The typical plant was defined by assumptions made in Table 48. Mean surcharges for typical plants were calculated to be about $400 per month beyond volume surcharges.

Actual sewer and surcharge values as determined in the NABADA survey will be given later in this section. However, in NABADA technical forums some representative costs were discussed. A medium-sized Southern reconditioner pays from $500 to 750 per month for effluent discharges plus $150 per month for a sewer "tax". A sizable Great Lakes area plant pays $100,000 per year for an 80,000 gallon (302,833 liter) per day discharge. This is contrasted with a smaller operation which pays about $1,380 annually for its sewer user charge.

Normally, concentrations of pollutants used to establish surcharges are determined by analytical programs of local sewerage authorities. However, a few cities permit self-monitoring and sampling provided certain procedures are followed closely.

UTILITIES

Water Supply

More than 90 percent of water used by drum reconditioners is purchased from local public or private distribution systems. The remainder is supplied from wells located on the reconditioner's property. Charges for water vary widely. The NABADA survey determined that mean annual costs for water supply are $3,365. The standard deviation is ± $5,477, or 163 percent of the mean, which is illustrative of the wide range of costs.

If average water usage is assumed to be 56,781 liters (15,000 gallons) per day, then average costs for water are about $0.23 per 1000 liters ($0.86 per 1000 gallons). This compares favoraby with industrial water supply charges nationally.

Sewers

Sewer surcharges and their basis were discussed separately. In the NABADA survey, actual annual sewer charges were investigated. The mean cost was $5,889, with a standard deviation of ± $11,142 (189 percent of the mean). This figure may be compared with the calculated mean of $4,868 in Table 48. Hence, it would appear that sewer charges are in the $400 to $500 per month range for average-sized washing plants (about 1,000 drums/day). This calculates to be $0.023 per drum.

Other

A leading reconditioner claims that total utility costs for water, gas, and electricity (exclusive of sewer charges) are

TABLE 48

CALCULATED ANNUAL SEWER CHARGES

Assumptions: (for typical reconditioning plant)

BOD = 1262 mg/l
COD = 4011 mg/l
TSS = 1669 mg/l
TKN = 18.6 mg/l
P = 34.3 mg/l
pH = 11.4
Flow = 15,000 gal/day

29 30

(Values above taken from Tables 29 and 30)
Chlorine Demand = 100 mg/l

Charges:

1)	$4,736.25
2)	$4,451.67
3)	$5,953.55
4)	$7,833.81
5)	$9,272.37
6)	$4,660.58
7)	$1,981.20
8)	$2,312.02
9)	$2,995.97
10)	$7,805.81
11)	$1,549.65

Mean = $4,868.44
Standard Deviation = ± $2,600.38

about $0.264 per drum (updated to current dollar levels). Hence, if water costs per drum are $0.0123 (calculated using figures above), then annual gas and electric costs would be about $66,000 for a typically sized plant. Such utility costs are escalating rapidly, so the estimate could well be out of date soon.

A reconditioner has estimated electricity costs for shot blasting to be about $0.005 per drum.

RESIDUE DISPOSAL

o (underline

In the NABADA survey, it was determined that the mean annual cost of solid waste disposal, including liquid waste hauling, was $11,578. The standard deviation was ± $17,443 (151 percent of the mean). This figure was compared with two other data bases: 1) results of the Checchi Report (4), and 2) the recent Temple, Barker and Sloane RCRA report (24). These latter two reports produce comparable results which were nearly four times the costs estimated in the NABADA survey. Using Checchi data, it was calculated that annual costs for residue disposal would be about $38,000 for a typical plant. Temple, Barker and Sloane data estimates disposal costs for a typical plant at nearly $44,000 per year assuming landfill for disposal. If incineration was used, costs would be about $237,000, or more than five times as much as landfilling.

The Checchi and Temple, Barker and Sloane landfill estimates work out to be $0.15 to $0.17 per reconditioned drum. These figures are slightly lower than Japanese residue disposal costs (Table 49).

TABLE 49

JAPANESE RESIDUE DISPOSAL COSTS

	Costs ($/drum)		
Plant Type	Depreciation (3 yr)	Operating Expense	Total
Large (1,500 to 3,000 drums/day)	0.10	0.10	0.20
Medium (1,000 to 1,500 drums/day)	0.15	0.10	0.25
Small (500 to 1,000 drums/day)	0.20	0.15	0.35

Because all of these costs antedate promulgation of RCRA regulations, it is expected that future costs will rise rapidly for those residues judged to be "hazardous".

CAPITAL

A 1975 survey by W&H Industries, Inc. (3) estimated pollution control expenditures for the 8-year period 1975 to 1983. Results of the survey are shown in Table 50. The survey team estimated that \$0.115 to \$0.138 would be added to the cost of each drum during that period, in addition to the then existing per drum costs for pollution control.

During the period 1976 through 1979, drum reconditioners spent 20 to 50 percent of their capital expenditures on environmental controls, according to an industry leader. Moreover, capital expenditures on environmental pollution abatement are expected to remain at that level at least through 1980. These data are based upon an informal survey of five large reconditioners in the greater than 1,500 drum/day range, and two larger than 3,000 drums/day.

Based upon the recent NABADA survey, it is estimated that U.S. reconditioners have about \$12,700,000 of installed pollution control equipment. Of this amount about \$9,100,000 is undepreciated (based upon 10-year life and straight-line depreciation). Hence, it is clear that most of the equipment is fairly new. Table 51 identifies types of pollution control equipment along with estimated capital costs and depreciation.

An additional amount of \$2,500,000 was claimed by reconditioners (\$1,000,000 undepreciated); however, the equipment was not judged as being related to pollution control.

A drum incinerator and afterburner in the 300 drum/hr size range a few years ago was estimated to cost about \$150,000. Some reconditioners claim that this estimate currently is too low. Pollution control equipment for washing plants costs from \$75,000 to \$200,000. For example, a wastewater treatment plant for a 1,200 drum/day washing plant in Japan costs about \$175,000. A manufacturer claims that a caustic cleaning unit for a typically sized plant would cost about \$28,000.

Recent requirements for hazardous waste treatment lead to expensive technology. For example, a 10 ton/hr hazardous waste incinerator rated at 200 million BTU/hr has a capital cost of \$30 million.

OPERATIONS AND MAINTENANCE

The NABADA survey determined that a typical reconditioning facility spends about \$45,000 annually for operations and maintenance related to pollution control. Table 52 shows the distribution of these expenditures. Most of the costs for

TABLE 50

POLLUTION CONTROL CAPITAL EXPENDITURES FOR THE PERIOD 1975 to 1983

(Reference No. 3)

Pollution Category	Expenditure (millions of dollars) FY 75-76	Expenditure (millions of dollars) 8 year total
Water Pollution Control	3.850	23.350
Solid Waste Management	0.190	19.000
Air Pollution Control	0.650	9.800
OSHA	0.735	8.700
Operation & Maintenance (direct)	0.435	8.600
Noise Control	0.750	5.350
Technical Services	0.215	2.400
Land Improvements	0.259	2.100
Other	0.812	7.300
Total	$7.896	$86.600

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TABLE 51

POLLUTION CONTROL EQUIPMENT
(in thousands of dollars)

Equipment Type	Capital Cost	Undepreciated Cost
Incinerators/Afterburners	5,100	3,600
Dust Collectors/Scrubbers	400	220
Paint and Spray Controls	970	580
Water Pretreatment & Treatment	4,740	3,620
Tanks & Clarifiers	830	580
Dissolved Air Flotation	430	340
Auxiliary Water Pollution Equipment	61	44
Water Filtration	170	138
Evaporator	34	17
TOTAL	12,735	9,139

TABLE 52

OPERATIONS AND MAINTENANCE COSTS FOR POLLUTION CONTROL (in thousands of dollars)

O & M Category	Annual O & M Cost
Incinerators/Afterburners	1,880
Dust Collectors/Scrubbers	28
Paint and Spray Controls	148
Water Pretreatment & Treatment	2,840
Tanks & Clarifiers	306
Dissolved Air Flotation	142
Auxiliary Water Pollution Equipment	3
Other	107
TOTAL	5,454

afterburners are for supplemental fuel.

COST/DRUM

A question on the NABADA survey asked for approximate unit costs per drum for pollution control. Responders claimed costs of $0.38/drum for washing and $0.35/drum for burning. An attempt was made to verify this figure in the following way. Component costs are: capital amortization, operations and maintenance costs, and residual disposal costs. Installed capital of $12,735,000 (from Table 51) at 8 percent interest (from 1977) for 10-year useful life was used to allocate amortization allowance. For 41,204,000 drums, the per drum cost is $0.067. Operations and maintenance costs from Table 52 yield a per drum cost of $0.132. Residue disposal costs for landfilling cited earlier were about $0.16. The total of these three elements is $0.36/ drum.

Values cited by reconditioners at technical forums have been updated to current costs. These are $0.37/drum for U.S. reconditioners and $0.44/drum for Japanese. Hence, it appears that NABADA survey figures are accurate. Additionally, it implies that reconditioners have good insight into various cost components. Recognize, however, that increased residue disposal costs, which historically have been the single largest component, are expected to rise significantly as RCRA regulations are implemented.

By comparison with pollution control costs, other drum unit costs are: abrasives - $0.04/drum, caustic - $0.14/drum, paint - $0.21/drum, and linings - $0.25/drum. These figures tend to be dated. Some reconditioners believe them to be low by nearly 50 percent.

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APPENDIX A

NABADA QUESTIONNAIRE

The following seven pages are the questionnaire sent by National Barrel and Drum Association, Inc. (NABADA) management to its membership. Omitted are questionnaire instructions and the letter of transmittal. The questionnaire was mailed late in January 1980. The original deadline of March 1, 1980, was extended by NABADA to March 15, 1980. Questionnaires continued to be received into April 1980. Touhill, Shuckrow and Associates, Inc. (TSA) informed NABADA that no questionnaires would be accepted after April 30, 1980. None were received.

BARREL AND DRUM RECONDITIONING INDUSTRY STATUS PROFILE

(1) In what state is your reconditioning facility?

____

(2) In what NABADA region are you located?

- ☐ Eastern
- ☐ Central
- ☐ Western

(3) In your facility, do you?

- ☐ Wash
- ☐ Burn
- ☐ Both

(4) What is the maximum number of drums you can process per day *(design capacity)*?

Washing ____________ drums/day

Burning ____________ drums/day

(5) What is the average number of drums you have processed per day during the past year?

Washing ____________ drums/day

Burning ____________ drums/day

(6) What is your average hourly processing rate?

Washing ____________ drums/hour

Burning ____________ drums/hour

(7) How many drums currently are stored at your drum processing site?

____

(8) How many drums currently are stored away from your processing site?

____

(9) How many shifts do you operate per day?

- ☐ One
- ☐ Two
- ☐ Three

(10) What percentages of the drums that you process are the following sizes?

	Wash	Burn
55-gal	______ %	______ %
30-gal	______ %	______ %
Other	______ %	______ %

(11) What percentages of the drums that you process fall into the following categories?

	Wash	Burn
Resale	______ %	______ %
Service or Laundry	______ %	______ %
Discards	______ %	______ %

(12) Attached to this questionnaire are process flow diagrams for washing and burning operations. Would you please cross out operations not performed in your facility? Also, would you please rearrange or add operations as they pertain to your facility? *(See Figures I and II).*

(13) Over the period of about a year, what percentage of drums that you recondition contained the following materials immediately before the drums were received by you?

Food	________ %
Oil	________ %
Paint	________ %
Adhesives	________ %
Ink	________ %
Resins	________ %
Cleaning solvents	________ %
Industrial chemicals	________ %
Pesticides	________ %
Other *(please explain)*	
____________	________ %
____________	________ %
____________	________ %

(14) How many pesticide drums do you process per month?

Wash ____________ drums/month

Burn ____________ drums/month

(15) Do you refuse to process any kinds of drums?

- ☐ Yes
- ☐ No

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FIGURE I

WASHING FLOW DIAGRAM

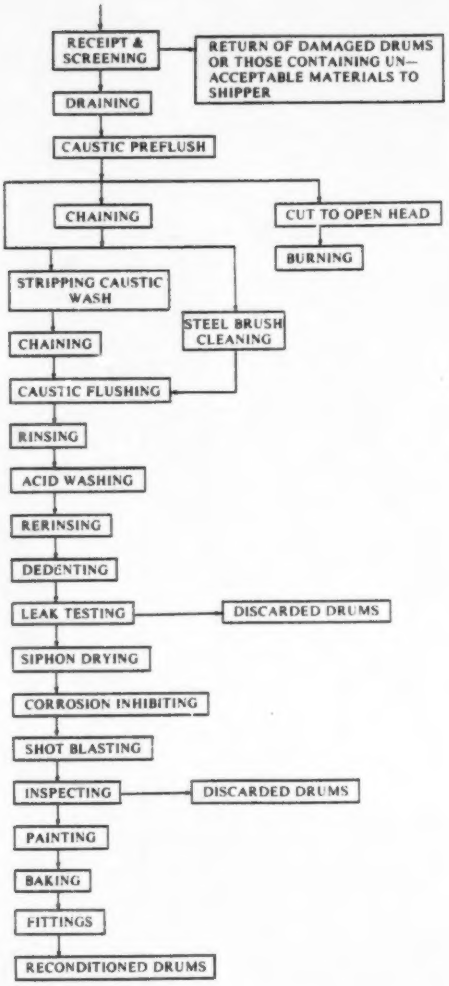
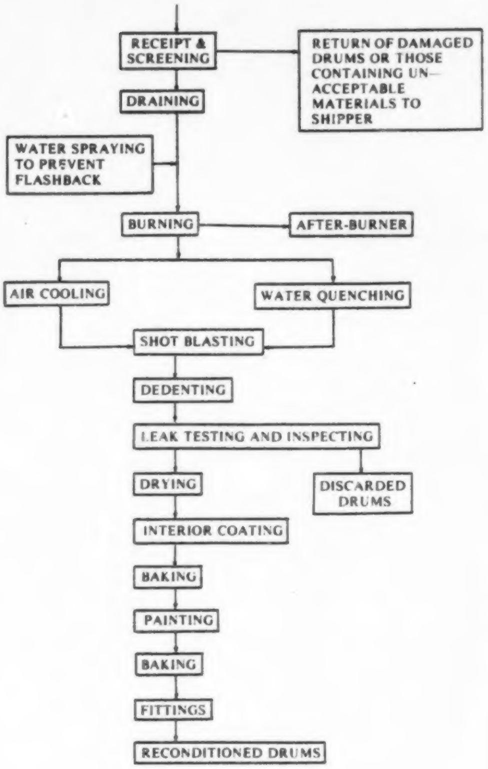

RECEIPT & SCREENING
RETURN OF DAMAGED DRUMS OR THOSE CONTAINING UN-ACCEPTABLE MATERIALS TO SHIPPER
DRAINING
CAUSTIC PREFLUSH
CHAINING
CUT TO OPEN HEAD
BURNING
STRIPPING CAUSTIC WASH
STEEL BRUSH CLEANING
CHAINING
CAUSTIC FLUSHING
RINSING
ACID WASHING
RERINSING
DEDENTING
LEAK TESTING
DISCARDED DRUMS
SIPHON DRYING
CORROSION INHIBITING
SHOT BLASTING
INSPECTING
DISCARDED DRUMS
PAINTING
BAKING
FITTINGS
RECONDITIONED DRUMS

FIGURE II

BURNING FLOW DIAGRAM


RECEIPT & SCREENING
RETURN OF DAMAGED DRUMS OR THOSE CONTAINING UN-ACCEPTABLE MATERIALS TO SHIPPER
DRAINING
WATER SPRAYING TO PREVENT FLASHBACK
BURNING
AFTER-BURNER
AIR COOLING
WATER QUENCHING
SHOT BLASTING
DEDENTING
LEAK TESTING AND INSPECTING
DRYING
DISCARDED DRUMS
INTERIOR COATING
BAKING
PAINTING
BAKING
FITTINGS
RECONDITIONED DRUMS

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(16) What kinds of drums do you refuse to recondition?
- ☐ Oil
- ☐ Paint
- ☐ Adhesives
- ☐ Ink
- ☐ Resins
- ☐ Cleaning solvents
- ☐ Industrial chemicals
- ☐ Pesticides
- ☐ Other *(please explain)* ____________

____

(17) If you have restrictions on the kinds of drums you will accept, would you please attach a copy of your instructions to your customers?

Copy attached:

- ☐ Yes
- ☐ No
- ☐ Do not have written instructions
- ☐ Do not have restrictions

(18) Do you recover oil?
- ☐ Yes
- ☐ No

(19) What do you do with the recovered oil?
- ☐ Sell to reprocessor
- ☐ Burn
- ☐ Landfill
- ☐ Give away
- ☐ Other *(please explain)*

____

____

(20) How much oil do you recover per month?

____________ gallons

(21) From start to finish, how long does it take an average drum to pass through your facility?

Washing ____________ minutes

Burning ____________ minutes

(22) Do you have your own wastewater treatment facility?
- ☐ Yes
- ☐ No
- ☐ Not a washing facility

(23) If the answer to question number 22 was "Yes", please describe the plant by attaching a flow diagram and a list of suppliers of major equipment items.
- ☐ Description enclosed
- ☐ Description not enclosed (please explain)

____

____

(24) Please check any of the following equipment that you currently use.
- ☐ Flush-o-matics
- ☐ Caustic filters
- ☐ Vacuum drying systems
- ☐ Automated flushers
- ☐ Automated upenders
- ☐ Oil/water separators
- ☐ Screens for gross particle removal
- ☐ Dissolved air flotation
- ☐ Flocculation/Sedimentation
- ☐ Coagulant feeders
  (please specify coagulants)

  ____

  ____

  ____
- ☐ Activated carbon sorption
- ☐ Biological treatment
  (please specify method)

  ____

  ____

(25) Are you performing any innovative treatment?
- ☐ Yes
- ☐ No

(26) If the answer to question number 25 was "Yes", please describe the innovation, and if appropriate, provide a flow diagram.

(27) What is the daily flow from your washing operation to public sewers or your own treatment plant?

____________ gallons/day
- ☐ Not a washing facility
- ☐ Do not send any wastewater to sewers or treatment plant *(please explain)*

____

____

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(28) Please indicate below wastewater treatment plant efficiencies for the parameters shown.

☐ Not a washing facility

Parameter (center)	**% Removal**
BOD *(biochemical oxygen demand)*	________
COD *(chemical oxygen demand)*	________
Suspended Solids	________
Oil and grease	________
Phenol	________
Cyanides	________
Lead	________
Zinc	________
Nickel	________
Copper	________
Chromium	________
Cadmium	________
Pesticides	________
TOC *(total organic carbon)*	________
Volatile organics	________
pH change from ______	to ________
Others	________
________	________
________	________

If possible, please note above the waste stream treated, e.g. caustic rinse solution, quench water, etc.

(29) Without identifying your company, please send copies of any analytical reports for wastewaters from washing operations. *(Please note that the more actual data we receive, the greater the assistance that can be offered.)*

☐ Not a washing facility
☐ Analyses enclosed
☐ No enclosures

(30) Do you segregate any wastewater streams?

☐ Yes
☐ No
☐ Not a washing facility

(31) At what concentration is your caustic?

Preflush ____________%

Caustic washing ________%

☐ Not a washing facility

(32) At what temperature do you keep your caustics?

Preflush ____________°F

Caustic wash ________°F

☐ Not a washing facility

(33) What percentage of drums do you chain?

__________%

☐ Not a washing facility

(34) What is the concentration and acid type of your acid wash?

______acid ______concentration

☐ Do not acid wash

(35) At what pressure do you operate your hydraulic dedenter?

____________________ psi

☐ Use a mechanical dedenter

(36) At what pressure are drums leak tested?

__________ psi

(37) What do you do with your caustic washing solutions?

☐ Discharge to public sewer
☐ Neutralize and discharge to public sewer
☐ Neutralize and discharge to stream
☐ Recycle and reuse
☐ Treat at own treatment plant and discharge to stream
☐ Discharge some and recycle some
☐ Not a washing facility

(38) What do you do with your rinsing solutions?

☐ Discharge to public sewer
☐ Discharge to stream
☐ Treat and discharge to stream
☐ Not a washing facility

(39) Please attach a copy of the basis for any sewerage surcharge, e.g. cost per 1000 gallons of flow, per pound of suspended solids or BOD, etc.

☐ Copy attached
☐ No enclosure
☐ Not surcharged
☐ Not a washing facility

(40) Check the water quality parameters which you measure or for which you are monitored. Also check those included in sewer regulations. If there is a regulation parameter checked, please put the required amount stipulated by the agency.

☐ Not a washing facility

	Measured	**In Regulation**	**Amount**
BOD *(biochemical oxygen demand)*	☐	☐	______
COD *(chemical oxygen demand)*	☐	☐	______
Suspended Solids	☐	☐	______
Oil and grease	☐	☐	______
Phenol	☐	☐	______
Cyanides	☐	☐	______
Lead	☐	☐	______
Zinc	☐	☐	______
Nickel	☐	☐	______
Copper	☐	☐	______
Chromium	☐	☐	______
Cadmium	☐	☐	______
Pesticides	☐	☐	______
Total organic carbon *(TOC)*	☐	☐	______
Volatile organics	☐	☐	______
pH	☐	☐	______
Other________	☐	☐	______

(41) Has your wastewater ever been analyzed for priority pollutants?

☐ Yes
☐ No

(42) If the answer to question 41 was "Yes", would you please enclose a copy of the analysis?

☐ Copy enclosed
☐ No enclosure
☐ Analysis not made

(43) Do you collect surface water runoff?

☐ Yes
☐ No

(44) If you collect runoff, what do you do with it?

☐ Discharge to public sewer
☐ Discharge to stream
☐ Treat and discharge
☐ Do not collect

(45) On the average, how much residue is left in the drums when you receive them?

☐ Less than ½ gal
☐ ½ to 1 gal
☐ 1 to 3 gal
☐ 3 to 5 gal
☐ More than 5 gal

(46) What is the average daily amount of drainage and/or residue you collect from drums before processing?

Liquid________________gallons
Sludge ________________pounds

(47) What do you do with concentrated liquids drained from received drums?

☐ Discharge to sewer
☐ Have contractor haul away
☐ Dispose to land on-site
☐ Burn on-site
☐ Send to landfill
☐ Other *(please explain)*

____

____

(48) What do you do with solid residues from drum drainage and other sludges generated in the reconditioning process?

☐ Discharge to sewer
☐ Have contractor haul away
☐ Dispose to land on-site
☐ Burn off-site
☐ Send to landfill
☐ Other *(please explain)*

____

____

(49) What do you do with ash from burning operations?

☐ Not a burning facility
☐ Dispose with other sludges
☐ Landfill
☐ Have contractor haul away
☐ Discharge to sewer
☐ Other *(please explain)*

____

____

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EPA-287 (Cin.)
(4-76)

(50) What do you do with clean discarded drums?
- ☐ Landfill
- ☐ Sell for scrap
- ☐ Sell for other use
- ☐ Return to customer
- ☐ Other *(please explain)*

____

____

(51) About how many drums that have had some processing are discarded during a weekly period?

__________drums/week

(52) If they are sent to a scrap dealer, are they:
- ☐ Crushed first
- ☐ Sent intact

(53) Do the scrap firms:
- ☐ Send their trucks
- ☐ You use your trucks

(54) What do you do with unprocessed discarded drums?
- ☐ Landfill
- ☐ Sell for scrap
- ☐ Return to customer
- ☐ Other *(please explain)*

____

____

(55) Do you have an afterburner on your furnace?
- ☐ Yes
- ☐ No
- ☐ Not a burning facility

(56) What percentage of the time that the furnace is in operation do you use the afterburner?

__________%
- ☐ Not a burning facility

(57) Do you have any air pollution control equipment other than an afterburner, at your burning facility?
- ☐ Yes
- ☐ No
- ☐ Not a burning facility

(58) If the answer to question 57 was "Yes", please describe the equipment, e.g. type, manufacturer, etc.
- ☐ Description attached
- ☐ Description as follows:

(58)

____

____

(59) At what temperature do you operate your furnace?

__________°F
- ☐ Not a burning facility

(60) At what temperature do you operate your afterburner?

__________°F
- ☐ Not a burning facility

(61) At what rate do you move drums through the furnace?

From __________ft/min to

__________ft/min
- ☐ Not a burning facility

(62) Do you vary the drum rate through the furnace in order to control air emissions?
- ☐ Yes
- ☐ No
- ☐ Not a burning facility

(63) On the average, how long is a drum in the furnace?

__________minutes
- ☐ Not a burning facility

(64) What is the length of your furnace?

__________feet
- ☐ Not a burning facility

(65) Over what length are there burning nozzles?

__________feet
- ☐ Not a burning facility

(66) Do you monitor furnace off-gases?
- ☐ Yes
- ☐ No

If the answer is "Yes", please indicate parameters measured.

____

____
- ☐ Not a burning facility

(67) What are the operating parameters of your shot blaster?

____

____

(68) Check those requirements, permits, ordinances which you must file or with which you must comply.

- ☐ EPA National Pollutant Discharge Elimination System *(NPDES)* permits, applications, and quarterly reports
- ☐ Federal, state, or local pretreatment requirements
- ☐ Air quality permits
- ☐ Solid waste disposal permits
- ☐ Local ordinances *(please explain)* ____________________
  ____
- ☐ Other *(please explain)* ____________________
  ____

(69) It would be extremely helpful if you could attach copies of the requirements, permits, and ordinances to which you are subject. Before submitting such information, please remove any identification of your firm.

- ☐ Copies enclosed
- ☐ No enclosures

(70) How much water do you use at your plant per month?

__________ gallons/month

(71) Where does the water come from?

	%
☐ Buy from city or water company	_____
☐ Your own well	_____
☐ Other *(please explain)*	_____

____
____

(If more than one, please indicate percentage from each).

(72) What are annual charges to you for:

Water	$ __________
Sewers	$ __________
Solid waste disposal	$ __________

(73) Please indicate the current cost in your area for:

New tight head drum	$ __________
New open head drum	$ __________
Reconditioned tight head drum	$ __________
Reconditioned open head drum	$ __________
Service or laundry fee per drum	$ __________

(74) Please indicate the capital costs you have expended for pollution control equipment. Indicate the type of equipment and the year purchased.

Equipment	**Capital Cost**	**Year Purchased**
__________	$ __________	__________
__________	$ __________	__________
__________	$ __________	__________
__________	$ __________	__________

(75) Please indicate your annual operating and maintenance costs for the pollution control equipment listed above in question number 74.

Equipment	**Annual O & M Cost**
__________	$ __________
__________	$ __________
__________	$ __________
__________	$ __________

(76) What are the approximate unit costs per drum for pollution control?

For washing: $ __________ /drum
For burning: $ __________ /drum

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EPA-287 (Cin.)
(4-76)

APPENDIX B

DRUM END USE CATEGORY DEFINITIONS

The following definitions for drum end use categories are quoted directly from the following reference: Current Industrial Reports. Steel Shipping Barrels, Drums, and Pails. Bureau of Census, M34K (70)-1 Report. U.S. Department of Commerce. March 1971.

Chemical - Includes chemical products not listed in another category: Agricultural chemicals, antifreeze, chemical bonding agents, coal tar products, detergents, dry cleaning agents, dyes, enzymes, finishes and coatings (excluding paint industry), insecticides, latex products, naval stores, oil additives, overpacks for plastic containers (chemical products), other heavy chemicals, petrochemicals, pharmaceuticals, plastic molding powders, synthetic resins, and wetting agents.

Petroleum - Includes products resulting from crude oil, excluding petrochemicals: Asphalt, diesel oils, fuel oils, gasoline, kerosenes, lubricating greases and oils, medicinal oils, petrolatum solvents, transformer oils, white oils.

Paint - Includes paint products: Lacquers, linseed oil, paints, pigments, thinners, varnishes.

Janitor Supplies, Industrial Maintenance - Buffing material, deodorants, detergents, disinfectants, industrial cleaning compounds, shampoos, waxes.

Food - Includes edible food products: Bakery supplies, edible meat products, edible oils--animal and vegetable, fish products, frozen foods, fruit concentrates, molasses, overpacks for plastic containers (food), preserves, shortening, sugar products, syrups.

All Other - Metallic powder, tote barrels, mill balls, steel chain, machine parts, drinking water, storage, glass marbles, rags, coal samples, wire, water samples, floating stock, swimming pool filters, trash.

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